



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
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CHICAGO, ILLINOIS 60604

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BY FEDERAL EXPRESS

July 18, 1991

REPLY TO ATTENTION OF:
5HS-11

Joe Adams, P.E.
Warzyn Engineering Inc.
2100 Corporate Drive
Addison, Illinois 60101

Re: Feasibility Study Comments - American Chemical Services Site -
Griffith, Indiana

Dear Mr. Adams:

Enclosed you will find U.S. EPA comments on the Draft Feasibility Study Report for the ACS site. The following Agencies and companies participated in the review of the document: U.S. Department of the Interior, U.S. Army Corps of Engineers, Indiana Department of Environmental Management, U.S. Geological Survey, U.S. EPA's Water, Air and Waste Management Divisions and Roy F. Weston Inc.

There are six attachments to this letter which comprise the comment package. Attachment 1 is the body of comments on the FS Report. Attachment 2 is a listing of U.S. EPA Water Pollution Control ARARs. Attachment 3 is a listing of ARARs forwarded by the IDEM. Attachments 4 through 6 correspond to references in Attachment 1, and Attachment 7 is a body of potential ARARs/comments forwarded by the U.S. Army Corps of Engineers. Attachments 3 & 7 are to be considered relevant comments, as if they had been included under Attachment 1.

I would like to schedule a meeting for the week of August 5 to discuss these comments. Please contact me as soon as possible to arrange a time and place for the meeting.

Also, with this letter, I am formally announcing my departure from the Agency for a position at Argonne National Laboratory, effective August 9, 1991. I hope to have a replacement who will take over my duties for this site, attend the above-referenced meeting.

If you have any questions please do not hesitate to call me at
(312) 886-5116.

Sincerely,



Robert E. Swale
Remedial Project Manager

Enclosures

cc: John Manley, IDEM
Dan Sparks, FWS
Jim Burton, Roy F. Weston
Jean Palensky, USACE

**ATTACHMENT 1
FEASIBILITY STUDY REVIEW COMMENTS
AMERICAN CHEMICAL SERVICES SITE
GRIFFITH, INDIANA**

General Comments on the Feasibility Study Report

Griffith Municipal Landfill

The recently revised version of the Baseline Risk Assessment (BRA) includes an assessment of the Griffith Municipal Landfill. The BRA assumes that operation of the leachate collection system will be discontinued for the future site risk scenario and continues to be operated for the current site risk scenario. The BRA concludes that no current or future land use risk exists for the Griffith Landfill, and that the leachate collection system currently in-place, adequately prevents leachate from leaving the landfill. The BRA also concludes in the future site risk scenario, that leachate will be discharged to the wetlands surrounding the landfill, and would not reach potential future residences. This is based upon the assumption that future residences could not be established in the wetlands, since current wetland and waterway rules will remain in effect. At this time EPA is reviewing the BRA and ecological assessment and will withhold judgment until that review is complete. However, EPA is concerned with the effect that leachate discharge will have to future site trespassers and to future users of site groundwater who may build in areas bordering the landfill and adjacent wetlands. Additionally, the Ecological Assessment (EA) does not include an analysis of the effects that leachate discharge is likely to have to the surrounding wetland environments.

EPA will soon be writing comments on the EA and the BRA which will point out any deficiencies found in the reports. Since these comments will be forthcoming and may change the conclusions of the EA and the BRA for the landfill, the need to address the Griffith Municipal Landfill in the FS at the level of detail requested in the comments below, will be reserved until EPA approves the final BRA and EA. If the BRA and the EA show that the landfill presents an unacceptable risk to human health and/or the environment in the future or current risk scenarios, then the concept outlined below will apply to the Griffith Landfill in the FS.

The Griffith Landfill, if found to present a risk, will require a genuinely different type of remedial action than the remaining portions of the ACS site. The ACS site (excluding the Griffith Landfill) is composed of highly mobile and highly toxic industrial

wastes confined to distinct source areas. These source areas are known to have adversely affected the surrounding groundwater and soils. Conversely, the Griffith landfill meets the definition of a municipal landfill (which has recently been regarded by the Agency as having a unique set of characteristics and in turn a unique set of probable remedial actions). Accordingly, the Griffith Landfill should be separated from the rest of the ACS site in the FS report, since these two subsets of the ACS Site will be different in the approach taken by the Agency to address remedial action alternatives.

In general, the Griffith Landfill should be discussed in the FS within the context of its own section or subsection which outlines a series of distinct alternatives normally associated with remedial actions for municipal landfills. Recent guidance on conducting RI/FS' at municipal landfills should be referenced for additional information on the Agency's strategy for municipal landfills. Overall, the remedial action alternatives proposed for municipal landfills in the guidance, assume that containment will be the primary remedial action. This being so, it would be better to separate the two portions of the site based upon these inherent differences. This would then allow EPA to select a remedy for the Griffith Landfill separate from the remedy selection for the rest of the ACS site. This separation will then allow EPA to make the best decision for the different portions of the site.

Optimizing Off-Site Groundwater Pumping and Treatment

Discussion in the FS report concerning the remediation of contaminated "off-site" groundwater needs to be significantly modified. Discussion concerning the remediation of contaminated off-site groundwater, proposes groundwater containment through pumping and treatment rather than aggressive remediation as the overall remedy for contaminated groundwater off-site. U.S. EPA believes that a more comprehensive action should be committed to for the off-site areas. The FS should commit to remediating the off-site areas in an aggressive manner, seeking to remediate the off-site groundwater in as short a period of time as possible. This would be in accordance with the NCP's goal of restoring groundwater to beneficial use within a practicable amount of time. The current version of the FS does not seek to restore the aquifer to its beneficial use within a reasonable amount of time, but rather relies on a minimal effort to control the spread of contamination in the off-site areas and relies on a more passive system.

As stated in Section 3 of the FS, conventional pump and treat systems (i.e., extraction wells set in locations to for a capture

zone cone of depression) have demonstrated limited successes for remediating site groundwater contamination. This has been recently supported in the literature. However, the literature recognizes that groundwater remediation systems which focus on aggressive remediation are more effective than those which rely on plume containment. Basic pumping and treatment of the off-site areas may accomplish little in the way of actually cleaning up the contaminated groundwater but may merely tend to control migration of the plume. This does not conform to the interests of the FS and the NCP which seek to return the groundwater at the site to beneficial use in a reasonable amount of time. An aggressive pump and treat system for the off-site areas may include the placement of withdrawal and injection wells in the off-site areas in locations which will facilitate aquifer cleanup time and efficiency. A pump and treat system which in the beginning is sought to be optimized will likely be more successful than one which is not.

The enclosed paper (Attachment 4) shows that through the use of computer modeling, various pumping schemes may facilitate aquifer cleanup time. The example provided in the paper, discovered that reinjection significantly reduced cleanup time. In terms of the ACS FS, a model should be used to determine an estimate of the time required to complete cleanup of the "off-site" aquifer using various pump and treat scenarios (i.e., using different well configurations, number of injection and withdrawal wells, pumping rates, etc). The model should be able to provide sufficient information to compare the costs and benefits of various pumping and treatment systems thus enabling an estimation of the remedial cost and relative time to complete the remediation. As an example, present worth analysis of a pump and treat system expected to require 10 years to meet cleanup goals, may be more or less expensive than one estimated to require 30 years, or the pump and treat system taking 10 years may require a treatment system with 3 to 5 times the capacity as the presently foreseen system and may result in a significant increase in space required for a treatment plant.

Modification of Alternatives 3 and 6

During review of Chapter 4 of the FS report, it was noted that alternatives 3 & 6 are structured to assume that significant amounts of the semi-volatile compounds of concern are more likely to be left in place following primary treatment (i.e., thermal treatment) of the major source areas.

Since it was assumed that the primary treatment option in both of these alternatives would be treating the source areas, the question

came to mind concerning where the majority of semi-volatile compounds of concern posing unacceptable risk resided with respect to the VOCs and buried wastes proposed for primary treatment. To answer this question, a back-calculation was performed to determine the threshold values of 1×10^{-6} risk for the semi-volatile contaminants-of-concern in the buried wastes and soils. The back-calculation was performed using the future site risk scenario equations for adults having dermal contact with unearthed soils. By use of each semi-volatile compound-of-concern's individual slope factor and an assigned risk level of 1×10^{-6} , action levels for the semi-volatile compounds of concern were established. The following compounds were selected for analysis based upon their predominance in soil borings at the site, they are: bis(2-ethylhexyl)phthalate, bis(2-chloroethyl)Ether, PAHs, and isophorone.

Following the establishment of action levels, soil borings which had concentrations of these compounds equaling or exceeding the calculated threshold values were targeted. These boring locations were then used to plot the areas on a map. (See enclosed figures 1 through 5) Overlays of each compound were then created and compared to one another in terms of the location of risk areas. It was discovered for the most part, that the risk areas associated with each compound-of-concern tended to correlate with the risk areas for the other SVOC contaminants-of-concern and with the VOC areas outlined in the FS report (see enclosed Figure 6). A calculation of the total volume of contaminated material was then performed by summing the total of the areas and multiplying them by an average thickness of 15 feet. This calculation yielded a total volume of material exceeding the 10^{-6} action levels of approximately 78,000 yd³. It should be noted that this value is assumed to be fairly conservative, since it is not likely that the semi-volatile compounds of concern exceed the threshold value at all depths.

This investigation provides sufficient information to warrant further evaluation of the source areas in the FS. The example should provide sufficient direction to complete a reevaluation of the objectives of alternatives 3 & 6. Presently these alternatives include the removal of source areas and rely upon in-situ treatment to accomplish remediation of the remaining contaminated groundwater and soil. Alternative 3 seeks to remove the majority of contaminated materials, approximately 65,000 yd³ and relies on groundwater flushing and treatment to remove the remaining contaminants. Alternative 6 removes 35,000 yd³ of primarily liquid wastes, sludges and materials exceeding 2 percent total VOCs, and relies on dewatering and soil vapor extraction to remove the remaining contaminants amenable to soil vapor extraction. Alternative 6, proposes to leave semi-volatile contaminants in-place which may exceed the risk range of 10^{-4} to 10^{-6} .

For purposes of the FS, Alternatives 3 and 6 should explore the practicality of removing these semi-volatile contaminated soils to the 10^{-6} , 10^{-5} and 10^{-4} levels. Calculations of volume should be made to cleanup levels which correspond to action levels calculated for 10^{-6} , 10^{-5} and 10^{-4} risk levels. By performing these tasks, EPA could then make adequate risk management decisions balanced with the remaining nine criteria to select the best alternative for the site.

The modification of alternatives 3 & 6 would provide a more comprehensive array of alternatives for EPA to select from. The National Contingency Plan (NCP) (March 8, 1990) seeks to remediate through treatment those materials which present a principal threat (i.e., greater than the 10^{-4} risk level). The semi-volatile compounds at the site, present a principal threat in terms of the future site risk scenario. Provided with the current set of alternatives, EPA can only choose between remedies which will likely leave principal threat contaminants in place for long term containment, or remedies that propose complete removal of all contaminated soils and wastes. The NCP does not favor containment remedies except in those cases where it can be shown that any proposed treatment remedy will be technically impracticable. On the other hand, remedies that propose complete removal also have drawbacks. This concept should be carried through to the rest of the document.

Cost Estimates and Sensitivity Analysis

In general the cost estimates seem reasonable and probably fall within the -30%, +50% FS cost estimate guideline. However, in the following comments you will find requests for the basis of the cost estimates. It was expected that more backup information (cost assumptions, vendor quotes, etc.) would have been provided. This backup information could be provided on a notes page attached to each alternative and would allow the reviewer to feel more comfortable about the cost estimate for each line item. Attachment 5 is an example of the amount of detail which is expected for the cost estimates.

Another major comment is the need for a sensitivity analyses in the FS. Included below is a list of items that should be included in a sensitivity analysis.

A sensitivity analysis should be done as part of the cost-effective analysis. The purpose of the analysis is to determine if the conclusions of the cost-effective analysis will change if the original assumptions and estimates are incorrect. The sensitivity analysis should focus on the major cost items in each alternative

that are most susceptible to uncertainty estimation error. Specific items that should be included in the sensitivity analysis are:

- Volume of contaminated soil.
- Volume of buried waste.
- Groundwater extraction rate.
- Capital unit costs for buried waste, soil and groundwater treatment options.
- O&M unit costs for buried waste, soil and groundwater treatment options.

SPECIFIC COMMENTS

1. Page 1-2, Paragraph 3, Line 1 - Following the word at insert the words and near.
2. Page 1-3, Paragraph 3 - The location of these incinerators should be stated in this paragraph.
3. Page 1-3, Paragraph 5, Line 4 - Add the word to between the words respect and the.
4. Page 1-6, Paragraph 5, Line 2 - Capitalize the word the.
5. Page 1-8, Paragraph 2. The following statement, "and may provide some drainage" should be rewritten to state "these wetlands and Turkey Creek are hydrologically connected."
6. Page 1-9, Paragraph 1 - It has not been conclusively determined that surface water discharge do not leave the site. It is likely that the wetlands, groundwater and the surface water are interconnected, and provide for the minor off-site release of contaminants. This variable should be included in this discussion.
7. Page 1-9, Paragraph 3 - "The clay till is absent in some areas, and ranges in thickness to about 50 feet in others. The till is regarded as an aquitard..." These two sentences contradict each other. Please rephrase.
8. Page 1-16, Paragraph 1 - This portion of the landfill is also near the Off-site Containment Area, which contains these same compounds. It is likely that the Off-site Containment Area

is the greatest contributor to this contamination rather than the breakdown of waste materials in the landfill. Materials in the landfill would more likely provide a nutrient source activity rather than being the resulting end product.

9. Page 1-16, Paragraph 1 - Although you include data for the organic contaminants, no data is included for inorganics. Please include actual data for inorganics and not merely high, highest or most.
10. Page 1-26, Paragraph 4, Line 3 - the word at should be replaced with the word near.
11. Page 1-27, Paragraph 4, Line 3 - The word Contaminant should be replaced with the word Containment.
12. Page 1-28, Paragraph 1, Line 4 - See comment number 11 above.
13. Page 1-28, Paragraph 3 - The entire discussion of the risk assessment is written in a manner which gives the impression the risk assessment is a worthless exercise which greatly overestimates risk. Delete the first bold paragraph.
14. Page 1-28, Paragraph 3, Line 1 - The word apparent should be replaced with the word imminent.
15. Page 1-28, Paragraph 6, Line 2 - The words great deal, should be replaced with the words some degree.
16. Page 1-28, Paragraph 6, Line 2 - The sentence: Calculated risk estimates are not to be construed to necessarily represent actual risks. should be changed to: Calculated risk estimates are based upon reasonable worst case scenarios, and may or may not be realized at the site.
17. Page 1-28, Paragraph 6, Line 7 - The phrase: do not necessarily, should be replaced with may or may not.
18. Page 1-29, Paragraph 2, Lines 7, 8 & 9 - Any risk is of concern, although not all warrant remedial action. Therefore, delete below which risks are not considered to be of concern from lines 7-8. Delete from line 9, be acceptable and replace with warrant remediation.
19. Page 1-29, Paragraph 3 - A statement or paragraph should be added to the beginning of this section as an introduction to the current land use scenario. The introduction should explain the concept behind the current land use scenario. The current land use scenario should be presented as a

reasonable worst case situation that could occur if the site is left unchecked and unremediated with no action taken to minimize any migration from, or direct exposure to, contaminants at the site. This is necessary since this scenario represents one of the primary bases requiring remediation of the site. The viewpoint presented in the text seems to play more on the impossibility of any of the assumptions occurring.

20. Page 1-29, Paragraph 3 - Replace the second sentence with: The assumed degree of exposure to populations from the pathways in the risk assessment is based upon common assumptions which may or may not result in risk estimates that are conservative.
21. Page 1-29, Paragraph 4 - Following the second sentence, add the following sentence: Although these exposures were created hypothetically for this report, it is not inconceivable that these conditions may be realized in the future given current land use conditions.
22. Page 1-29, Paragraph 4, Line 5 - Remove the emphasis on the word hypothetical in this section (i.e., underlining). Also, delete the word hypothetical in line 5.
23. Page 1-29, Paragraph 4, Bullets - These risks may change as a result of recent revisions to the BRA. Please revise accordingly.
24. Page 1-30, Paragraph 1 - During the field work of the RI, it was noticed on different occasions that various individuals trespassed on the site. This observation was largely the result of observation of the evidence of trespassing, such as horse manure, burglary of the site trailer, and footprints in the wetland areas, etc. Based upon these observations and given the nature of trespassers (i.e., they do not normally trespass when workers are about) the conclusion that trespassing is hypothetical cannot be supported, and should be modified to reflect this comment. Additionally, the current owner of the Kapica/Pazmey property uses the property for his own uses. He is assumed to trespass regularly but has not been mentioned in the risk analysis.
25. Page 1-30, Paragraph 1 - Delete the word hypothetical at the beginning of the sentence.
26. Page 1-30, Paragraph 3 - The future land use scenario is based upon a reasonable worst case likelihood of site fate. The current discussion seems to place this scenario under the

assumption that people would never be exposed to site soils, etc., because inhabitation of the site is unlikely. This scenario may not occur since the future cannot be predicted, but it is nevertheless a reasonable worst-case scenario and should be treated as such in the document.

27. Page 1-31, Section 1.6.5 - This section needs to be reevaluated due to likely revisions to the Ecological Assessment. Please revise this section accordingly.
28. Page 2-2, Bullets 1 & 2 - Replace Control migration with prevent migration. In bullet 2 the objective should start Reduce or eliminate migration.
29. Section 2.1, Bullets - Wherever the risk range of 10^{-4} to 10^{-6} appears in the bullets, the following should be added to the sentence with a point of departure of 10^{-6} .
30. Page 2-2, Bullet 1 - The cleanup goals for the migration of contaminated groundwater to surrounding wetlands and sediments should be consistent with the risk levels found in the ecological assessment (i.e., a Hazard Quotient less than or equal to 1). Please revise accordingly.
31. Page 2-2, Bullets 9, 10, & 11 - See comment number 30 above.
32. Page 2-3, Bullets 1 & 2 - In both bullets, following the word leachate insert the following: contaminated soils, sediment, surface water and groundwater,.
33. Page 2-4, 2.4 Groundwater and Surface Water Remedial Technologies - Monitoring is retained. Monitoring is not a remedial technology. This should be addressed under another topic.
34. Page 2-6, Paragraph 3 - Water reinjection should be retained as a technology that could be used as part of an overall treatment system. It is conceivable that reinjection of treated groundwater could be used as a form of groundwater flushing to enhance aquifer cleanup, as a method of gradient control and to minimize the dewatering of site wetlands. It is agreed that gradient control as a form of site remediation (i.e., to inject clean city water to the aquifer to control gradient exclusively) is not feasible, and should not be retained as a primary technology.
35. Page 2-9, Freezing Technologies - This technology is eliminated because, "... has not been field tested on

contaminants present at the Site..." The NCP states (40 CFR 300.430 (e) (5)):

The lead agency shall develop one or more innovative treatment technologies for further consideration if those technologies offer the potential for comparable or superior performance or implementability; fewer or lesser adverse impacts than other available approaches; or lower costs for similar levels of performance that demonstrated treatment technologies.

Perhaps, a more appropriate logic should be included.

36. Page 2-10, Reverse Osmosis - The model AOC for RI/FS includes a clause which encourages the use of treatability studies. The need for a treatability study to determine the adequacy of a method, is not a valid reason for eliminating the technology from consideration.
37. Page 2-14, Paragraph 4 - Reinjection of treated groundwater should not be limited to biological treatment systems. Reinjection can be used to facilitate physical aquifer cleanup systems as well. Reinjection could also be used as a superior method of ensuring that portions of the site's wetlands would not be severely dewatered during "off-site" aquifer remediation and during dewatering of "on-site" source areas.
38. Page 2-15, Paragraph 2, Line 1 - Replace taken with used.
39. Page 2-19, Paragraph 1, Last Sentence - The explanation for releasing this process option from further consideration is due to the very high levels of contaminants found in the waste. This reasoning needs further explanation. For instance, what effect will high contaminant levels in the waste have on the operation of the system as a whole? Will it be dangerous to operate, or be inefficient and costly? Please explain.
40. Page 2-19, Paragraph 3 - Please elaborate more on the results of recent case studies, i.e., at which sites was this process option attempted and did not work. It is our understanding that different surfactants can be utilized to achieve different removal efficiencies. Provided with the site soil characteristics, soil washing should not be eliminated without some further justification.
41. Page 2-20, Paragraphs 3 & 4 - More detail is needed to justify the elimination of this process option due to the

difficulties likely to be experienced when treating soils. For instance, the original treatment system was mainly developed to treat transformer fluid, a primarily homogenous substance physically. What difficulties are likely to be experienced when treating a relatively heterogenous substance such as contaminated soils?

42. Page 2-21, Paragraph 2 - It is mentioned in this paragraph that wet air oxidation is used primarily as a treatment mechanism to treat complex organics where it is determined to be more cost-effective than incineration. In this FS report, incineration has been retained as a process option to be carried through to detailed analysis. Yet wet air oxidation has not, even though it is stated in the text that it may be chosen when it is deemed more cost-effective than incineration. In this case, no comparison has been made between incineration and wet air oxidation either in terms of cost or effectiveness. This discrepancy should be corrected in the text, since wet air oxidation if proven to be of equal quality to incineration, could be a viable alternative to a more controversial technology such as incineration.
43. Page 2-25 - At this point this portion of the document begins to fail in clearly identifying why each technology is eliminated from consideration. Please include a clear statement containing a NCP-valid reason for eliminating each technology.
44. Page 2-26, Paragraph 1 - Please explain further why radio frequency has not been retained for treating waste materials. No obvious justification is evident in the discussion to exclude this technology for waste materials at this time, please elaborate.
45. Page 2-27, Paragraph 4 - It is unclear which type of cover is being eliminated from further analysis in this paragraph. Is concrete only being eliminated, or concrete and asphalt? If both, then please note that asphalt caps are analyzed further in subsequent sections of the report. If concrete caps exclusively are being eliminated, then please clarify this in the discussion.
46. Page 2-29, Paragraph 1, Line 5 - The word "action" should be "active".
47. Page 2-29, Paragraph 4 - It should be clarified in this paragraph that leachate in the active portion of the Griffith landfill has been impacted by contamination coming from the off-site containment area. This is evidenced by an increase

of hazardous substance concentrations associated with the Off-site Containment Area in this part of the landfill. A check of the RI report should clarify this.

48. Page 2-29, Paragraph 4, Line 9 - Following the word leachate, insert the following: and the wastes themselves.
49. Page 2-30, Paragraph 2 - Regrading and revegetation of the existing landfill cover should also be considered in the listing of landfill process options.
50. Page 2-30, Paragraph 3 - A leachate collection system upgrade or expansion should also be considered in the listing of landfill process options. Additionally, it should be mentioned that the Village of Griffith currently uses the local POTW for discharge of leachate. This factor should be included to assess the degree of increased discharge that the POTW can treat.
51. Page 3-1, Paragraph 2, Line 6 - following the word contaminants, insert the word either. At the end of the last sentence please add the following text: or where contaminants are in a great enough concentrations that the efficiency of the primary system cannot treat or remove the contamination to the required performance standard.
52. Page 3-2, Paragraph 2, Line 9 - Delete the s from residuals".
53. Page 3-3, Bullet 3 - Please clarify what is meant by the assumption that the downgradient migration of groundwater originating from the off-site containment area, will be collected in the Griffith Leachate collection system. Does this imply that contaminated groundwater from the Off-site Containment Area currently discharging to the landfill and becoming leachate, will not be treated in the site groundwater treatment system, or is it assumed that the groundwater from the Off-site Containment Area will be treated in the Griffith leachate collection system during the remedial action?
54. Pages 3-3 to 3-5, Bullets - For each contaminant grouping, please explain why the compound representing that group was selected. For example, in the BETX grouping, why were benzene and toluene selected, is it because they were the most dominant compounds, the most mobile, the most toxic, or the most representative compounds for evaluating treatment system performance for their respective group?
55. Page 3-6, Paragraph 4, Line 3 - Delete very close.

56. Page 3-9, Paragraph 1, Line 3 - At the end of the sentence ending in this line, insert the following: and any additional monitor wells as warranted.
57. Page 3-11, Bullets - The following option for use of a slurry wall should also be considered. The placement of a slurry wall between the Off-site Containment Area and the Griffith landfill. The purpose of such a slurry wall being twofold. One being the hydraulic separation of the Griffith landfill and the Off-site Containment Area, and the second being the facilitation of dewatering activity in the Off-site Containment Area. Active dewatering of the Griffith Landfill resulting from a dewatering system designed to completely dewater the Off-site Containment Area, may not be cost-effective in light of the fact that high BOD/COD concentrations are likely to exist in the landfill leachate. Such high values for BOD/COD are likely to burden the groundwater treatment system. Also, separation by a slurry wall would reduce the volume of groundwater to be treated.
58. Page 3-12, Paragraph 3 - The cost of placing a slurry wall between the Griffith Landfill and the Off-site Containment Area, should be considered as well.
59. Page 3-13, Paragraph 2 - It would be helpful if the discussion of the computer modeling of groundwater extraction would include an analysis of changes in wetland hydrology.
60. Page 3-13, Paragraph 3 - It should be mentioned here that the removal of the fire pond will necessitate replacement of a structure or system to generate sufficient water for fire control. This should also be factored into the cost of the remedial action and the implementability issues likely to be faced by ACS.
61. Page 3-14, Paragraph 1 - An attempt should be made at this point to determine the likely impact that the lower aquifer groundwater extraction will have on the treatment system overall. The feasibility study throughout, assumes that a treatment system capable of treating at a maximum 300 gpm should be suitable to treat water from the site. This volume has not been conclusively estimated and needs to be for cost comparison and implementability issues. (see general comments above)
62. Page 3-15 - Discharging groundwater (treated or untreated) to the Hammond Sanitary District should mention their history of problems associated with pre- and post-treatment programs. Please insert this factor into the discussion.

63. Page 3-15, Paragraph 1 - The implementability section states that the Hammond POTW has sufficient capacity but no mention is made concerning the available capacity of the 12-inch sewer line.
64. Page 3-17, Paragraph 1, Line 2 - Insert at the end the sentence ending with treatment the following: or as part of an aggressive pump and treat system.
65. Page 3-17, Paragraph 2 - It should be mentioned in the discussion that in active groundwater pump and treat systems it may be advantageous to reinject the treated water to form a "closed loop" system of groundwater treatment. As mentioned earlier, this type of system should be modeled and considered a viable alternative not only as a means to facilitate cleanup, but also as a means to minimize damage to site wetlands which may result due to direct surface water discharge, or from dewatering.
66. Page 3-17, Paragraph 3 - There are some disadvantages to direct discharge of treated water to the site wetlands which should be mentioned. The major disadvantage being the radical change in the hydrologic balance which is likely to result. This will likely result in many species of plants and animals being eliminated or stressed due to the introduction of a current or increased volumes of water. This should be mentioned in the report.
67. Page 3-17, Paragraph 3 - It is unlikely that the discharge of treated groundwater will flush hydrophobic or Ph dependant compounds such as PCBs and metals from the wetland sediments.
68. Page 3-18, Paragraph 6 - Placing of a site fence prior to the implementation of other remedial actions may not always be practical. This statement should be qualified.
69. Page 3-19, Paragraph 4, Line 9 - Following the word covered insert the word with.
70. Page 3-19, Paragraph 5, Line 6 - Following the word The, insert the words: operating portion of.
71. Page 3-20, Paragraph 1 - Asphalt covers may still be required to meet the multimedia requirements, since HDPE or similar types of liners may be required along with a drainage medium to underlie the asphalt (the asphalt acting as the main barrier and the underlying drainage layer and liner acting as backup). This would be especially true if the asphalt cap were part of an long term containment option for PCBs and

semi-volatiles left following primary treatments, since RCRA closure ARARs will apply.

72. Page 3-20, Paragraph 2 - The assumption that a clay cap could be used to cover treated soils and eliminate the requirement for a multimedia cap may not be accurate in this case. This is especially true if contaminated soils are left in place following treatment. It is documented that the presence of these wastes can be attributed to RCRA listed waste processes and types which would trigger a RCRA cap requirement as relevant and appropriate.
73. Page 3-21, Paragraph 5 - Reference is made to Figures 3-3 and 3-4. These figures were not included in all copies of the FS.
74. Page 3-21, Paragraph 5 - Figure 3-3 and 3-4 were not included in all documents.
75. Page 3-27, Paragraph 2 - Although some influent groundwater would be expected to exceed 100 mg/l this factor may be influenced by dilution with other groundwater sources such as the lower aquifer and the "off-site" areas.
76. Page 3-38, Paragraph 1 - Delete In the revised National Contingency Plan (NCP), the U.S. EPA recognizes that contaminated soils and debris are significantly different than the waste streams used to develop the RCRA land-ban treatment standards. The U.S. EPA has developed provisions for obtaining an expedited variance from the RCRA land ban treatment standards for soil and debris at CERCLA Sites. This paragraph should be replaced with a complete discussion of why a variance may be appropriate. Please refer to OSWER Directive 9347.3 - 06FS. This directive addresses what should be contained in the FS on this topic.
77. Page 3-38, Paragraph 1, Last Sentence - At the end of this sentence add the following: or risk based levels.
78. Page 3-41, Paragraph 1 - U.S. EPA Region 5 recently signed a ROD for the ACME Solvents Site which included Low Temperature Thermal Treatment (LTTT) as a primary treatment option. Also various vendors have provided information which shows that some of the compounds seemingly not amenable to LTTT may indeed be amenable but at a higher temperature. Some literature from these vendors has been attached for your information (Attachment 6). It is hoped that this information will be included in the discussion.

79. Page 3-53, Paragraph 3 - This paragraph ends without a period.
80. Page 3-54, Paragraph 4, Line 4 - Following the word permeability insert: and high ionic bonding affinity.
81. Page 3-57, Paragraph 1 - The assertion that the landfill leachate has not been affected by wastes from the ACS site are unfounded. It is apparent, and is stated in the RI report, that the Off-Site Containment Area has probably impacted the leachate in the active portion of the Griffith Landfill. This should be corrected.
82. Page 3-57, Paragraphs 2 & 3 - The landfill measures mentioned here in the text should be removed consistent with the discussion at the beginning of these comments.
83. Page 3-58, Paragraph 1 - See comment number 82 above
84. Page 3-58, Paragraph 1 - This section says there is an apparent difference in data collected from the active and inactive portions of the landfill, but does not adequately explain what the difference is and why it should not have an impact on remediation. Later sections of the FS, including section 4.4.10.1, state that there is no difference in the data. Please remedy these concerns.
85. Page 3-59, Paragraph 4, Line 4 - Delete the word or.
86. Page 3-61, Paragraph 1 - Please explain in the text, the reason why both thermal treatment options are retained for above ground treatment but biological treatment is not retained. Above ground biological treatment is retained for alternative 8 to treat waste and soils but is not considered as a treatment option for buried wastes in alternative 6. Please document these reasons in the text or change the discussion to include biological treatment as a viable above-ground treatment option.
87. Page 4-2, Paragraph 1, Last Sentence - The last sentence states that the concentrations listed in Tables 4-1 through 4-6 should not be construed as cleanup levels. What cleanup levels were assumed as part of the detailed analysis of alternatives. A table summarizing the assumed cleanup levels would be helpful.
88. Page 4-3, Paragraph 1 - Give an example of how the potential minimum soil design concentrations were established.

89. Page 4-5, Paragraph 3, Line 2 or line 3 - The words be selected should be removed as it is redundant.
90. Page 4-8, Paragraph 1 - State the basis for assuming the 5% discount rate used in the cost effectiveness analysis. An 8% discount rate seems more reasonable.
91. Page 4-9, Paragraph 1 - Please include in the description of the slurry wall dewatering system, the expected pumping rate for initial dewatering and steady state dewatering, similarly to the estimates outlined for Section 4.2.3.
92. Page 4-9, Paragraph 3, Line 3 - Replace the word feasibility with consequences.
93. Page 4-10, Paragraph 1 - This section states that the pumping rate would reduce to 80 gpm after 120 days. Section 3.3.3, p. 3-1, 3rd paragraph states that the pumping rate would be reduced to 80 gpm after 1 year. Which is correct?
94. Page 4-10, Paragraph 1 - Figure 4-8 is "On-site Incineration Schematic". Correct the figure reference.
95. Page 4-10, Paragraph 2 - The fourth sentence states a series of sixteen to twenty groundwater extraction groupings are shown on Figure 4-8. Figure 4-8 displays an on-site incinerator schematic.
96. Page 4-11, Paragraph 2 - As mentioned in the general comments at the beginning of these comments, a proper modeling scheme is needed to determine the probable pumping and treatment rate required to remediate the "off-site" areas. No modeling has been completed on the off-site area to determine the probable flowrate required for treatment of an aggressive groundwater treatment system.
97. Page 4-12, Paragraph 2 - It should be mentioned that there are various uncertainties associated with the lower aquifer groundwater contamination. Although contamination in the lower aquifer is orders of magnitude less than the upper aquifer, it is a widely used drinking water source. Limited action risks the possibility that contamination may disperse further into the lower aquifer system thus increasing remediation costs at a later time. Another uncertainty includes the penetration depth of the screened interval in the lower aquifer monitoring wells. These wells only penetrate the first five to ten feet of the lower aquifer and may not represent the true extent of contamination. This is especially true considering the substances detected are the

degradation by products of compounds with densities greater than freshwater. Finally, it should be mentioned that only one well represents the known extent of contamination in the lower aquifer. Considering this, it would be possible higher risk concentrations or substances are as yet undiscovered.

98. Page 4-14 - Please include some discussion concerning problems that may occur with the wetlands in case media drains were used for groundwater extraction. For instance they could cause more disturbance, and can have more permanent impacts than wells which can be shut-off when remedial actions are complete.
99. Page 4-14, Paragraph 1 - Figure 4-8 is "On-site Incineration Schematic". Correct the figure reference.
100. Page 4-15 - The proposal to pipe extracted groundwater 4,000 feet for discharge to Turkey Creek is undesirable. It is likely that a great deal of additional disturbance could result from this action, including additional impacts to wetlands. Please include this concept in the revised FS.
101. Page 4-15, Paragraph 1 - Figure 4-8 is "On-site Incineration Schematic". Correct the figure reference.
102. Page 4-16 - The discussion of "flushing" contaminants from the wetlands using a pump, treat, and discharge system may have some possibilities with regard to soluble and volatile contaminants present in wetland sediments and groundwater. However, for the metal contamination and the hydrophobic organic contaminants, this system is unlikely to be effective. Decisions as to how to handle these low solubility contaminants will have to be based on the revised Ecological Risk Assessment. There are several possibilities in this regard: 1) an accurate risk assessment indicating low risk based on source control; 2) only localized sediment contamination in the wetland that can be handled via hotspot sediment removal; or, 3) reevaluation of off-site remedial alternatives due to significant widespread ecological risks. Additionally, the reinjection of treated groundwater should not be limited to participation in a biological treatment system.
103. Page 4-17, Paragraph 1 - Asphalt and concrete caps are mentioned as possible long term containment methods in this discussion, yet they may have been eliminated from further consideration due to their susceptibility to crack from differential settlement. Please clarify this in the discussion. The discussion should also include that capping

may be used to prevent short circuiting of the vapor extraction system and limit the dewatering of the upper aquifer due to excess precipitation.

104. Page 4-18, Sections 4.2.7.1, 4.2.7.2, 4.2.7.3, and 4.2.7.4 - Each of these sections contains a process option-specific list of removal efficiencies and final effluent concentrations based on available data sources. It would be helpful if a table is presented that applies the removal efficiencies to the groundwater concentrations given in Table 4-7 and then compares them to the groundwater treatment design criteria given in Table 4-14.
105. Page 4-20, Paragraph 1 - Are complex organic ions expected to exist in the current groundwater system, and if so, how will they effect the implementability of this process option?
106. Page 4-20, Paragraph 1 - Figure 4-9 is On-site Low Temperature Thermal Treatment Schematic. Correct the figure reference.
107. Page 4-26, Paragraph 1 - Figure 4-10 is Buried Waste & Soil Biological Treatment Plan. Correct this figure reference.
108. Page 4-26, Paragraph 2 - Figure 4-9 does not correspond with the discussion.
109. Page 4-28, Last Paragraph - It should be mentioned that the "off-site" treatment system will likely dilute the on-site groundwater such that UV/Oxidation may be feasible for a primary system.
110. Page 4-29, Last Paragraph - Figure 4-10 is Buried Waste & Soil Biological Treatment Plan". Correct this figure reference.
111. Page 4-32, Paragraph 2, Line 3 - The word containment should be changed to contaminant.
112. Page 4-32, Paragraph 3 - Ion bacteria should iron bacteria.
113. Page 4-33, Paragraph 1 - The problem of discharging warm water to natural surface water needs to be discussed in this portion of the report. The discharge of temperate water to local streams and wetlands may be detrimental to these waters. Also, various local state and federal ARARs are likely to triggered by such a system. Please include a discussion.

114. Page 4-34, Paragraph 1 - Figure 4-13 is In-situ Steam Stripping Schematic. Correct this figure reference.
115. Page 4-35, Paragraph 3 - Figure 4-14 is In-situ Fixation Schematic. Correct this figure reference.
116. Page 4-37, Paragraph 2 - Delete sentences 4 and 5. Replace them with a complete discussion of why a variance on land-ban treatment standards may be appropriate (see comment number 76)
117. Page 4-37, Paragraph 3 - Figure 4-16 is In-site Soil Vapor Extraction Schematic. Correct this figure reference.
118. Page 4-38, Paragraph 2 - A listing of the contaminants of concern, similarly to the list of contaminants for groundwater treatment options (i.e., a discussion of the effectiveness of the system to treat these compounds) would be beneficial to this discussion. For example, how does this system perform with regard to semi-volatile ketones, phenols, etc.?
119. Page 4-38, Paragraph 3 - Please explain how mixing will be accomplished in the landfarm treatment system. It is widely known that thorough mixing is necessary to enhance and ensure that proper decomposition is occurring in the treatment zone.
120. Page 4-38, Paragraph 4 - Figure 4-17 was not included in the document.
121. Page 4-39, Section 4.2.10.1 - See comment number 84 above.
122. Page 4-40 - The No Action alternative may include monitoring.
123. Page 4-40 - All alternatives will need: Time to Implement, O & M Costs, and Present Net Worth.
124. Page 4-41 to 4-46. Alternative 2.) In the brief description of the alternative, 1) "...surface soils would be covered to prevent dermal contact." It might be better to state what type of cover is envisioned (e.g. soil, clay cap or multi-layer cap). 2) Are the ARARs identified? 4) Is slurry wall installation near RR tracks contemplated?
125. Page 4-42, Paragraph 1, Line 5 - Following the word discharged insert the words or reinjected.

126. Page 4-42, Paragraph 2 - Mention of the Griffith landfill should be removed from this discussion, since it will be covered in a separate section of the report.
127. Page 4-42, Paragraph 3 - Off-site groundwater contamination would be subject to a performance standard for cleanup, comparable to a corrective action program under RCRA Subpart F (40 CFR 264.100). Long term monitoring would not meet ARARs.
128. Page 4-43, Paragraph 2 - RCRA Subpart F would also have to be complied with, as well as the relevant landfill closure regulations, since these wastes would be considered to be RCRA derived wastes. This conclusion is based upon the type of wastes accepted by ACS in the past. Provided this, RCRA would be considered relevant and appropriate.
129. Page 4-43, Paragraph 4 - The off-site groundwater remediation system would be expected to be aggressively remediated through a modern pump and treat system. It is expected that during active remediation of the aquifer the system would be optimized and changed accordingly to obtain the most efficient results for the most rapid aquifer cleanup.
130. Page 4-44, Paragraph 1 - Dewatering by the Griffith Landfill is a temporary condition and should not be counted upon for evaluation of the FS. Please remove this presumption from the document.
131. Page 4-46, Paragraph 2 - The dewatering system mentioned in the first sentence needs to be described rather than referenced, since section 4.3.2 refers to a slurry wall. The description seems to be describing a dewatering system that would not use a slurry wall. Please clarify this.
132. Page 4-46, Paragraph 3 - This alternative should include a statement which states that following removal of the buried wastes and their treatment on-site, the groundwater pump and treat system will then be optimized to determine the most efficient means by which to remediate the aquifer. These means may be the implementation of an in-situ biological treatment system, or it may mean the placement of injection and withdrawal wells to facilitate cleanup. Natural flushing, continuous monitoring, and pumping and treatment of the groundwater system for thirty years is not acceptable for this alternative.
133. Page 4-46, Paragraph 4 - Treatment of contaminated soils can also be accomplished by flushing them with an infiltration

basin to flood the vadose zone soils. This may also promote an increase in biological activity which could also facilitate vadose zone cleanup. This concept should be included with this alternative.

134. Page 4-46, Paragraph 4 - The reference to the Griffith landfill should be removed due to its separation from the listing of alternatives.
135. Page 4-47, Paragraph 1 - Please provide a more thorough explanation of how two percent was chosen as the cutoff point for the treatment of buried wastes in this alternative. Will it be possible to remove contaminants from the vadose and water table with a groundwater pump and treat system when they are probably at residual saturation levels? A lower number of less than 5000 ppm may be more realistic for the proposal to flush contaminants from the subsurface.
136. Page 4-47, Paragraph 2 - It should be mentioned that if low temperature thermal treatment were to be utilized with a catalytic incinerator, off-gases from the air stripping system and, from a vapor extraction system, could also be directed to the catalytic incinerator which may help reduce costs and concern for residual fate.
137. Page 4-47, Paragraph 2 - Figures 4-12, 4-13, and 4-14 are not as described in this section. Correct these figure references.
138. Page 4-47, Paragraph 2, Lines 3 & 5 - Delete ~~may dictate~~, or interfere with, the location of the and replace with ~~may be considered in locating an~~. In line 5, the sentence should end: ...Figure 4-12 to avoid interfering with ACS's operations.
139. Page 4-48, Paragraph 3 - Since it is proposed that residuals in excess of 10^{-6} risk level would be left in place following removal, then RCRA closure ARARs may apply. These clean standards would not approach the RCRA ARAR for clean closure and would therefore be triggered. This would then necessitate a RCRA cap or equivalent to contain the residual materials if further treatment were to be ruled out. However, proposed regulations for Subpart S Corrective Action may speak on this subject as well, and may provide some guidelines concerning ARARs that could be defined as: to be considered.
140. Page 4-49, Paragraph 2 - The groundwater treatment process option of air stripping is mentioned here as a proposed

process option for groundwater treatment. It was thought that the groundwater treatment technology would be selected separately from the selected remedy. Please clarify this. Also, please mention that, if air stripping were to be selected for the groundwater option, off-gases from the system could be collected and transferred to the catalytic incinerator that would be in use for the LTTT system.

141. Page 4-49, Paragraph 3 - Discussion of an aggressive groundwater pump and treatment system should replace discussion of a natural flushing system for the remediation of the aquifer. As discussed previously in these comments, a pump and treat system that seeks to obtain the best removal efficiency should be sought. Biological treatment or treatment which utilizes artificial flushing by injection or by infiltration basins should be placed here.
142. Page 4-50, Paragraph 2 - It is understood that for purposes of cost estimation the groundwater pump and treat system is expected to operate for 30 years. However, it should be mentioned in this section of the analysis that an aggressive groundwater pump and treat system will be expected to remediate the aquifer to appropriate cleanup levels in a shorter period of time.
143. Page 4-50, Paragraph 4 - Implementability issues should also discuss the potential movement of ACS equipment to remove buried wastes. It is known that many of the waste areas underlie process and storage tanks at the facility. Also, many structures lie on the perimeter of these areas and may be structurally compromised during the onset of remedial action activities. Since ACS is a signatory to the RI/FS consent order, the FS should include a statement to the effect that ACS agrees or is aware of the implementability of some of the alternatives. While access issues can be overcome during remedial action, EPA needs this information, in terms of the implementability of the various alternatives to arrive at a balanced remedy selection. The best way to facilitate this would be to place a statement in the FS report which outlines the position of an ACS officer such as John Murphy.
144. Page 4-51 - The title to alternative 4 should include the off-site incineration of buried drums and miscellaneous debris.
145. Page 4-51, Paragraph 4 - Mention of the Griffith landfill in the description should be removed, since it will have its own section.

146. Page 4-51, Paragraph 5 - Figure 4-18 was not included in the document.
147. Page 4-52, Paragraph 2, Line 2, replace treat times with treatment time.
148. Page 4-55, Paragraph 2 - It is mentioned here that organic acids, isophorone, phthalates, PNAs and PCBs are not expected to be mobile within the upper aquifer groundwater and are not expected to present much of a problem. However, this assumption does not account for the future site risk scenario. This scenario of the BRA assumes that on-site residents will be exposed to subsurface materials unearthed as a result of future site development. Although institutional controls could be implemented, there is limited guarantee that these controls would be enforced or heeded in the future. This should be mentioned in the discussion here.
149. Page 4-55, Paragraph 3 - Figure 4-19 was not included in the document.
150. Page 4-57, Paragraph 5 - See comment number 144 above concerning additions to this alternative's title. Also, the removal of Kapica/Pazmey soils should be included in the title, since these soils are surface soils and are not expected to be adequately treated by vapor extraction.
151. Page 4-58, Paragraph 3 - Figures 4-20 and 4-21 were not included in the document.
152. Page 4-58, Paragraph 4 - The Verona Well Field Superfund site contaminant summary reveals that the highest VOC concentrations were near 100 mg/kg in the vadose zone soils. For purposes of this discussion indicate how the design parameters referenced from the Verona site will correlate with the likely concentrations to be found at the ACS site.
153. Page 4-59, Paragraph 3 - The VOC removal rates mentioned in this paragraph are not consistent with the removal rates mentioned in the ARARs section of the analysis. The inconsistency may be due to assumptions concerning the length of the day, etc. Please correct these inconsistencies.
154. Page 4-59, Paragraph 4 - It needs to be stated in this paragraph that the off-site groundwater treatment system will be optimized and that groundwater injection may be part of that effort. Also, it should be mentioned that it is unlikely that PCBs and other semi-volatile compounds would be "flushed" from wetland sediments during discharge.

155. Page 4-60, Paragraph 2 - This additional sentence should be added to this paragraph: A disadvantage to this type of treatment is that it will not eliminate the risk of semi-volatile contaminated soil contact to future site users.
156. Page 4-60, Paragraph 2 - Please discuss in this paragraph or the following paragraphs, the possibility that it may be difficult to extract volatile compounds due to the large number of semi-volatiles contained in the waste matrix. It is possible that SVOCs bind up VOCs in the waste matrix rendering soil vapor extraction technology more difficult.
157. Page 4-60, Paragraph 4 - The capping of residual SVOCs and PCBs would have to meet RCRA and TSCA technical standards for cap placement and long term monitoring. Please add this ARAR to the discussion.
158. Page 4-60, Paragraph 4 - The VOC emission rate cited in the discussion does not correlate with the extraction rate discussed previously in the alternative description. Please remedy this inconsistency.
159. Page 4-62, Paragraph 2 - Again, it must be stated that some immobile semi-volatile compounds are compounds of concern in the future land-use scenario and present a risk in excess of the risk range.
160. Page 4-62, Paragraph 3, Line 1 - Replace the word is with the word are
161. Page 4-64, Paragraph 1 - Please include the following sentence at the end of this paragraph: However, proper capping of the on-site areas could aid in minimizing these problems by reducing the amount of infiltration into the vapor extraction areas.
162. Page 4-64, Bullet 5 - Following the word wells insert the following:, reducing soil moisture.
163. Page 4-65, Paragraph 3 - The removal of "buried wastes" should be consistent with the general comments for alternatives 3 & 6 above.
164. Page 4-65, Paragraph 4 - The possibility of using a catalytic incinerator in conjunction with the SVE system and air stripper should be mentioned in this discussion. It is important to recognize that a single destruction method could be common to different extraction systems, and could be used cost-effectively.

165. Page 4-66, Paragraph 2, Line 6 - Following the end of this sentence, add the following words: or reinjected.
166. Page 4-66, Paragraph 3 - An in-situ vapor extraction system could be installed concurrently with the implementation of thermal treatment in some areas. This is especially true in those areas which are not currently undergoing excavation and thermal treatment, but would at the time be fully or partially dewatered. This should be mentioned in the text.
167. Page 4-69, Paragraph 2 - The following ARARs should be added to this discussion: Discharge or reinjection to the site wetlands or upper aquifer, and RCRA Subpart F groundwater corrective action regulations.
168. Page 4-71, Paragraph 4 - Treated groundwater could also be reinjected into the upper aquifer as part of an aggressive groundwater treatment system, and to aid in the control of excessive dewatering of site wetlands. Also, reference to the Griffith Landfill should be removed since it will be discussed under a separate section of the FS.
169. Page 4-72, Paragraph 1 - The advantages of using an air stripper with the LTTT system should be mentioned in this portion of the report.
170. Page 4-73, Paragraph 1 - The enclosed vendor literature should be referenced when assessing the viability of using LTTT for the remediation of PCB and SVOC contaminated soils.
171. Page 4-73, Paragraph 3 - According to the enclosed literature, LTTT will probably achieve desired cleanup levels for many of the semi-volatile compounds purported to be possibly nonamenable to LTTT. The referenced literature should be discussed in the body of the report.
172. Page 4-74, Paragraph 2 - The reduction of toxicity, and volume is not demonstrated for future site users. Future site users would not be protected by immobilization of PCBs from the upper aquifer groundwater, since the future site user is exposed to unearthed soils on-site. This section of the detailed discussion should address this possibility.
173. Page 4-74, Paragraph 2 - The last sentence states that a discussion pertaining to U.S. EPA guidance documents for PCB contaminants is in Section 4.3.5. No reference could be found in Section 4.3.5.

174. Page 4-76, Paragraph 2 - Again, reinjection should be mentioned here as a method for operating an aggressive groundwater treatment system and to aid in controlling the dewatering of site wetlands. Also, discussion of the Griffith Landfill should be eliminated from the discussion.
175. Page 4-78, Paragraph 2 - The proposed landfarming option would have to follow RCRA regulations pertaining to waste piles. These regulations would necessitate the placement of a cover to minimize precipitation exposure and to relieve the requirement for a groundwater monitoring system. Also, the waste pile would have to be located at an area designated to lie within the current area of contamination (AOC). A waste pile lying outside of the present AOC would be required to first meet land disposal restrictions (i.e., possibly pretreatment of the wastes) prior to deposition in the waste pile. This ARAR may place severe limitations on the implementability of this alternative and should be explored further.
176. Page 5-1 - A section should be reserved for the discussion of the nine criteria as they pertain to the Griffith Landfill. The Griffith Landfill should be examined separately from the hazardous waste disposal areas and should be evaluated separately.
177. Page 5-1, Paragraph 2, Line 4 - The acronym BRA should be changed to the acronym RI.
178. Page 5-1, Paragraph 2, Line 5 - End the sentence beginning in line 4 by following the word Site with a period. Following this, insert the following text prior to the phrase: the no action., and begin the next sentence: However, the BRA's current and future land use scenarios show that.
179. Page 5-1, Paragraph 2 - The following sentence should be added at the end of this paragraph: Alternative 1 would also do nothing to prevent future site users from being exposed to unearthed soils resulting from future development of the site.
180. Page 5-1, Paragraph 3, Line 3 - The word would should be replaced with the word may.
181. Page 5-1, Paragraph 3, Line 4 - Following the word wetlands insert the following: or reinjected as part of an overall groundwater remediation system designed; and delete the following phrase from this sentence: located west of the Site.

182. Page 5-1, Paragraph 3, Line 6 - Following the word sediments insert the words and upper aquifer.
183. Page 5-2, Paragraph 1 - The protection afforded by Alternative 2 to future site users is far less than the protection afforded future site users in the other alternatives. Alternative 2 would rely solely on capping and deed restrictions to minimize the direct contact threat to future site users. Alternative 3 would (if semi-volatiles are removed as per previous comments to a risk based level) minimize the future site users contact with on-site materials and would control and remove contaminated groundwater. Alternatives 4 & 5, would leave semi-volatiles in place and would rely on a cap and deed restrictions to minimize future site users' exposure to site contaminants. However, the treatments used in these alternatives may reduce concentrations of SVOC contaminants to a lower level. Alternative 6, (if semi-volatiles are removed as per previous comments) would reduce future site user's chance of contacting SVOC contaminated soils by removing them, and treating the remaining VOC contamination by soil vapor extraction. Alternatives 7 & 8 would significantly reduce or remove all on-site contaminated soils and would rely on the in place groundwater pump and treat system to remedy the remaining VOC contamination in the "off-site" areas to MCLs.
184. Page 5-2, Paragraph 3 - Alternative 2 would only reduce migration of contaminants in the groundwater but would only marginally reduce the possibility of exposure to contaminated soils by future on-site users of the facility.
185. Page 5-3, Paragraph 4, Line 3 - The acronym BRA should be changed to RI/BRA. In the same line, the word current should be changed to the word imminent.
186. Pages 5-3 & 5-4 - The discussion concerning long term effectiveness and permanence seems to ignore the fact that containment as proposed in alternative 2 would include a number of uncertainties concerning the actual performance of the cap and slurry wall over time. The actual permanence of this alternative does not equal the permanence likely to be experienced from Alternative 3 and does not reach the level of permanence achieved if Alternatives 7 or 8 were selected. This discussion also does not discuss the overall permanence of the alternatives with respect to the uncertainty associated with continued land disposal and possible future uses of the site. Alternative 2, with the exception of the No Action alternative poses the most risk for exposure under the current and future land use scenarios, given the

uncertainties of land disposal. Alternatives 7 and 8 provide the most protection to future site users by eliminating the majority of site risks under both the current and future land use scenarios. This discussion needs to be rewritten to reflect the uncertainties of land disposal, and the degree of uncertainty that will remain following implementation of each alternative.

187. Page 5-5, Paragraph 2 - In the discussion it is assumed that the more immobile compounds found in the site soils would be eliminated from concern in each alternative due to the subsurface nature of their locations. However, this discussion does not address the role of the risks apparent to future on-site users of the site. It is assumed in the future site risk scenario that on-site users would be in contact with mixed surface and subsurface soils which contain semi-volatile compounds. Dermal absorption, and not ingestion drives most of the risk for the future site use scenario to the SVOC compounds of concern (i.e., isophorone, PCBs, PAHs, bis (2-ethylhexyl)phthalate etc.). This discussion should include the inherent uncertainties associated with long term land disposal and the relevance this has with regard to an evaluation of those alternatives which are likely to leave these compounds in the subsurface.
188. Page 5-6, Paragraph 3 - The toxicity and volume of soil contaminants is not significantly reduced in Alternative 2. Alternative 2 merely controls and possibly reduces contamination over a long period of time. It is misleading to represent alternative 2 as equal in its effect to the next 6 alternatives. The time it will take to achieve the same levels of reduction in toxicity and mobility for alternative 2 versus that for alternatives 7 or 8 should be factored into this discussion.

Figures

189. Page 2-23, Paragraph 4 - Steam stripping is discussed in this section but has not been included on Figure 2-1 under in-situ treatment of buried waste. It should be included and then "shaded" to indicate that it has not been carried forward.

Tables

190. Table 2-1, Page 2 - Vapor extraction should be added to the list of in-situ physical treatment process options listed for buried wastes.

191. Table 2-3 - The "Landfill" column should be removed from this listing since it is anticipated that the landfill will be undergoing its own separate evaluation.

Appendices

192. Appendix A - It does not appear that proposed groundwater treatment of the lower aquifer would have a large impact on the shallow groundwater aquifer (and thus the wetlands), but it would be helpful if this would be clarified.
193. Appendix C - DIRECT CAPITAL COSTS

Surface Water Diversion

A lump sum cost of \$200,000 is given for all alternatives. This cost and the fact that it is the same for all alternatives seems reasonable. However, providing a more detailed breakdown of the components of the lump sum cost estimate and the associated costs would lend more credibility to the cost estimate.

Some of the alternatives include provision for cover of contaminated areas with concrete, asphalt and/or soil. Is this cover cost included in the surface water diversion cost item? If not, where is the cost included?

Site Preparation

A lump sum cost of \$525,000 for Alternatives 3A, 3B, 5, 6A, 7A, and 7B; \$475,000 for Alternative 4; and \$535,000 for Alternatives 8A and 8B has been given. The cost estimates and minor variations between alternatives seem reasonable, however a more detailed breakdown of the components of the lump sum costs and reason for the variations would lend more credibility to the cost estimate.

Groundwater Extraction System

Alternative 2: What is the basis for assuming 6 groundwater extraction wells? The groundwater modeling results in Appendix A (Simulation REM 1) assumes 12 groundwater extraction points.

Based on the 6 groundwater extraction wells given, the cost per extraction well is approximately \$33K. This seems to be a relatively high cost given the shallow aquifer and low pumping rate.

Alternatives 3A, 3B, 5, 6A, 6B, 7A, 7B, 8A, and 8B: What is the basis for assuming 24 groundwater extraction wells? Section 4.2.3 discusses 16 to 20 groundwater extraction groupings.

Based on the 24 groundwater extraction wells given, the cost per extraction well is approximately \$21K. What is the reason for the difference between this unit cost per well and that given for Alternative 2?

Alternative 4: What is the basis for assuming 6 groundwater extraction wells?

Based on the 6 groundwater extraction wells given, the cost per extraction well is approximately \$83K. What is the reason for the difference between this unit cost per well and that given in the other alternatives?

Groundwater Treatment System

Alternative 2: What is the basis for the 100 gpm groundwater treatment rate? Section 3.3.3, p. 3-14, paragraph 3 states that the initial pumping rate would be 175 gpm and would reduce to 20 gpm after the first year.

How was the \$800,000 estimate cost of the 100 gpm groundwater treatment system derived from the \$1,200,000 estimated cost of the 200 gpm groundwater treatment system given in Table 4-15?

Alternative 4: What is the basis for the 150 gpm groundwater treatment rate?

How was the \$1,000,000 estimated cost of the 150 gpm groundwater treatment system derived from the \$1,200,000 estimated cost of the 200 gpm groundwater treatment system given in Table 4-15?

Remove ACS Tank Farms

A lump sum cost of \$150,000 is given for all alternatives. This cost and the fact that it is the same for all alternatives seems reasonable. However, providing a more detailed breakdown of the components of the lump sum cost estimate would lend more credibility to the cost estimate.

Excavation of Drums

A unit cost of \$100 per drum is given for all alternatives. This cost and the fact that it is the same for all alternatives seems reasonable. However, providing the basis for this cost estimate (vendor quotes, etc.) should lend more credibility to the cost estimate.

Repackaging and Off-Site Incineration of Drums

A unit cost of \$700 per drum is given for all alternatives except Alternative 4. This cost seems reasonable with regard to the -30%, +50% FS cost estimate guideline. However, providing the basis for this cost estimate (vendor quotes, etc.) would lend more credibility to the cost estimate.

Why was a unit cost of \$400 per drum used for Alternative 4?

Off-Site Disposal of Drums and Miscellaneous Debris

A lump sum cost of \$1,000,000 is given for all alternatives. This cost and the fact that it is the same for all alternatives seems reasonable. Making a cost estimate for such an unknown is difficult. Providing the assumptions used in making the cost estimate would lend more credibility to the cost estimate.

Slurry Wall

A unit cost of \$8.62 per sq. ft. is given for Alternative 2. This cost seems reasonable with regard to the -30%, +50% FS cost estimating guideline. However, providing the basis for this cost estimate would lend more credibility to the cost estimate.

Trial Burn

A lump sum cost of \$200,000 is given for Alternatives 3A, 6A and 7A. This cost estimate and the fact that it is the same for all alternatives seems reasonable. However, providing the basis for this cost estimate would lend more credibility to the cost estimate.

On-Site Incineration

A unit cost of \$450 per cubic yard was given for Alternatives 3A, 6A and 7A. What is the basis for using this unit cost? Table 3-5 gives a unit cost of \$370 per cubic yard.

Treatability/Pilot Studies

All alternatives involve one or more treatability/pilot studies. The lump sum costs range from \$200,000 to \$400,000. These costs and the fact that they are consistent across all alternatives seems reasonable.

On-Site Low Temperature

A unit cost of \$300 per cubic yard was given for Alternatives 3B, 6B and 7B. What is the basis for using this unit cost? Table 3-5 gives a unit cost of \$185 per cubic yard.

In-Situ Steam Stripping

A unit cost of approximately \$560,000 per auger is given for Alternative 4. Providing the basis for this cost estimate (vendor quotes, etc.) would lend more credibility to the cost estimate.

Vapor Extraction

A unit cost of \$200,000 per system is given for Alternatives 5, 6A and 6B. Providing the basis for this cost estimate (vendor quotes, etc.) would lend more credibility to the cost estimate.

Landfarming

What is the basis for the \$2,500,000 cost estimate given for Alternative 8A. Providing the basis for this cost estimate (vendor quotes, etc.) would lend more credibility to the cost estimate.

Slurry-Phase Bioreactor

What is the basis for the \$6,000,000 cost estimate given for Alternative 8B. Providing the basis for this cost estimate (vendor quotes, etc.) would lend more credibility to this cost estimate.

Off-Site Disposal of PCB Soil at RCRA/TSCA Landfill

A unit cost of \$700 per cubic yard is given for Alternative 5. This cost seems reasonable with regard to the -30%, +50% FS cost estimate guideline. However, providing the basis for this cost estimate (vendor quotes, etc.) would lend more credibility to the cost estimate.

INDIRECT CAPITAL COSTS

The indirect capital cost percentages are typical of those used at FS level cost estimating. Overall, the indirect capital costs seem reasonable with regard to the -30%, +50% FS level cost guideline. The indirect capital costs also seem reasonable when compared between alternatives.

OPERATION AND MAINTENANCE COSTS

Groundwater Monitoring

An annual O&M cost of \$200,000 for 30 years is given for all alternatives. This cost seems reasonable based on inclusion of labor and analytical costs for quarterly monitoring of the number of ACS monitoring wells. The fact that the cost is consistent across all alternatives is also reasonable.

Groundwater Extraction Wells

An annual O&M cost of \$65,000 for 30 years is given for all alternatives except Alternative 2. Providing cost estimate assumptions would lend more credibility to the cost estimate.

Why is the annual O&M the same for Alternative 4 which has fewer wells and a lower pumping rate?

Groundwater Treatment

Table 4-15 gives an annual O&M cost of \$685,000 for a 200 gpm air stripping/ion exchange treatment facility. What is the basis for using an annual O&M of \$750,000 (combined initial, intermediate, final groundwater treatment O&M) for Alternatives 3B, 5, 6A, 6B, 7A, 7B, 8A and 8B that also have a 200 gpm capacity?

In-Situ Steam Stripping

Alternative 7 gives an annual O&M cost of \$2,700,000 for 10 years. What is the basis for this cost estimate. Providing cost estimate assumptions would lend more credibility to this cost estimate.

Vapor Extraction

Alternative 5 gives an annual O&M cost of \$400,000 for 15 years and Alternatives 6A and 6B gives an annual O&M cost estimates of \$400,000 for 5 years. What is the basis for these cost estimates? Providing cost estimate assumptions would lend more credibility to the cost estimate.

Soil Excavation

Alternatives 8A and 8B give annual O&M costs of \$300,000 for 10 years and \$600,000 for 5 years. What is the basis for these cost estimates? Providing cost estimate assumptions would lend more credibility to the cost estimate.

Landfarming

Alternative 8A gives an annual O&M cost of \$600,000 for 10 years. What is the basis for this cost estimate? Providing cost estimate assumptions would lend more credibility to the cost estimate.

Slurry-Phase Bioreaction

Alternative 8B gives an annual O&M cost of \$2,200,000 for 5 years. What is the basis for this cost estimate? Providing cost estimate assumptions would lend more credibility to the cost estimate.

Insurance

Why is the annual O&M for Alternatives 6A and 6B less than Alternatives 3A, 3B, 7A and 7B that include the same incineration technologies?

Why is 1 year used in Alternative 3A and 3B when the source treatment is anticipated to last 3 years?

Reserve Fund

Why is the annual O&M for Alternatives 6A and 6B less than Alternatives 3A, 3B, 7A and 7B that include the same incineration technologies?

Why is only 1 year used in Alternative 3A and 3B when the source treatment is anticipated to last 3 years?

Administration

An annual O&M cost of \$200,000 for 30 years is given for all alternatives. This cost seems reasonable. Providing cost estimate assumptions would lend more credibility to the cost estimate.

Number of Years

The number of years used in the present worth analysis seems appropriate based on the duration given in the text. It would be helpful if the basis for using the number of years was given in footnotes or references given to the appropriate section of text.

COST EFFECTIVENESS/PRESENT WORTH ANALYSIS

The total indirect capital cost for Alternative 4 should be \$5,220,000 instead of \$3,980,000. The resulting total net present worth for Alternative 4 should be \$50,600,000 instead of \$49,400,000.

FIGURE 1

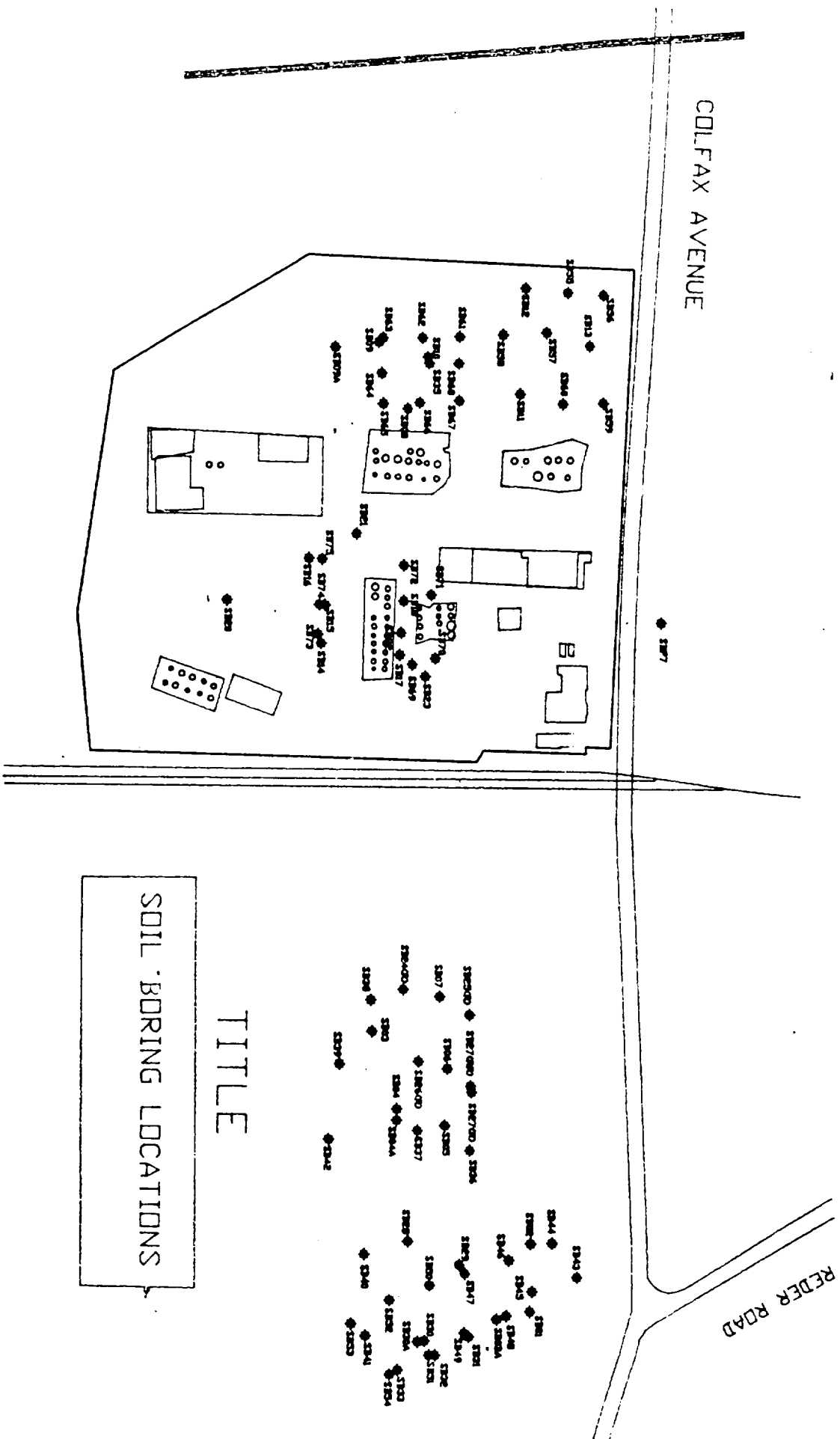


FIGURE 2

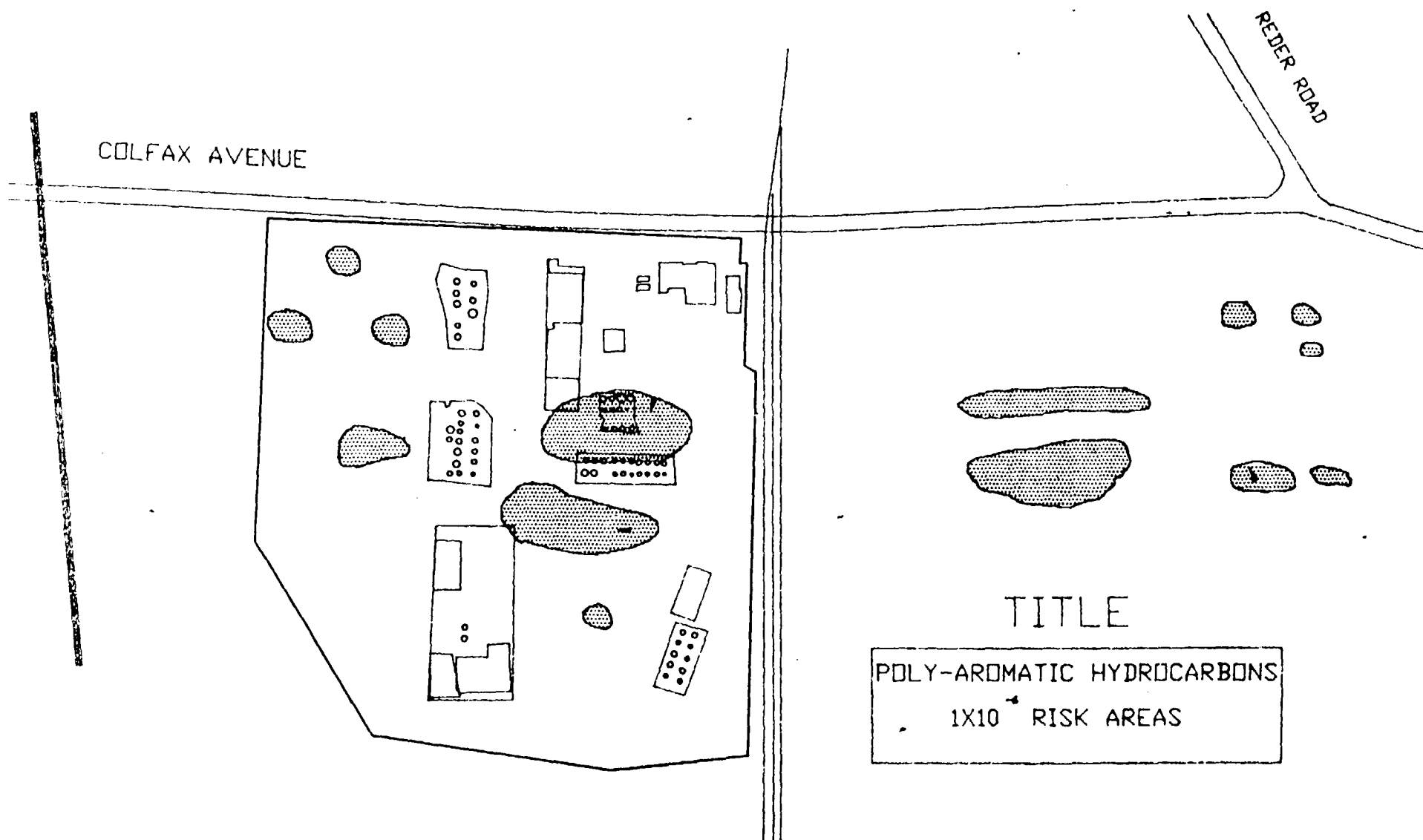


FIGURE 3

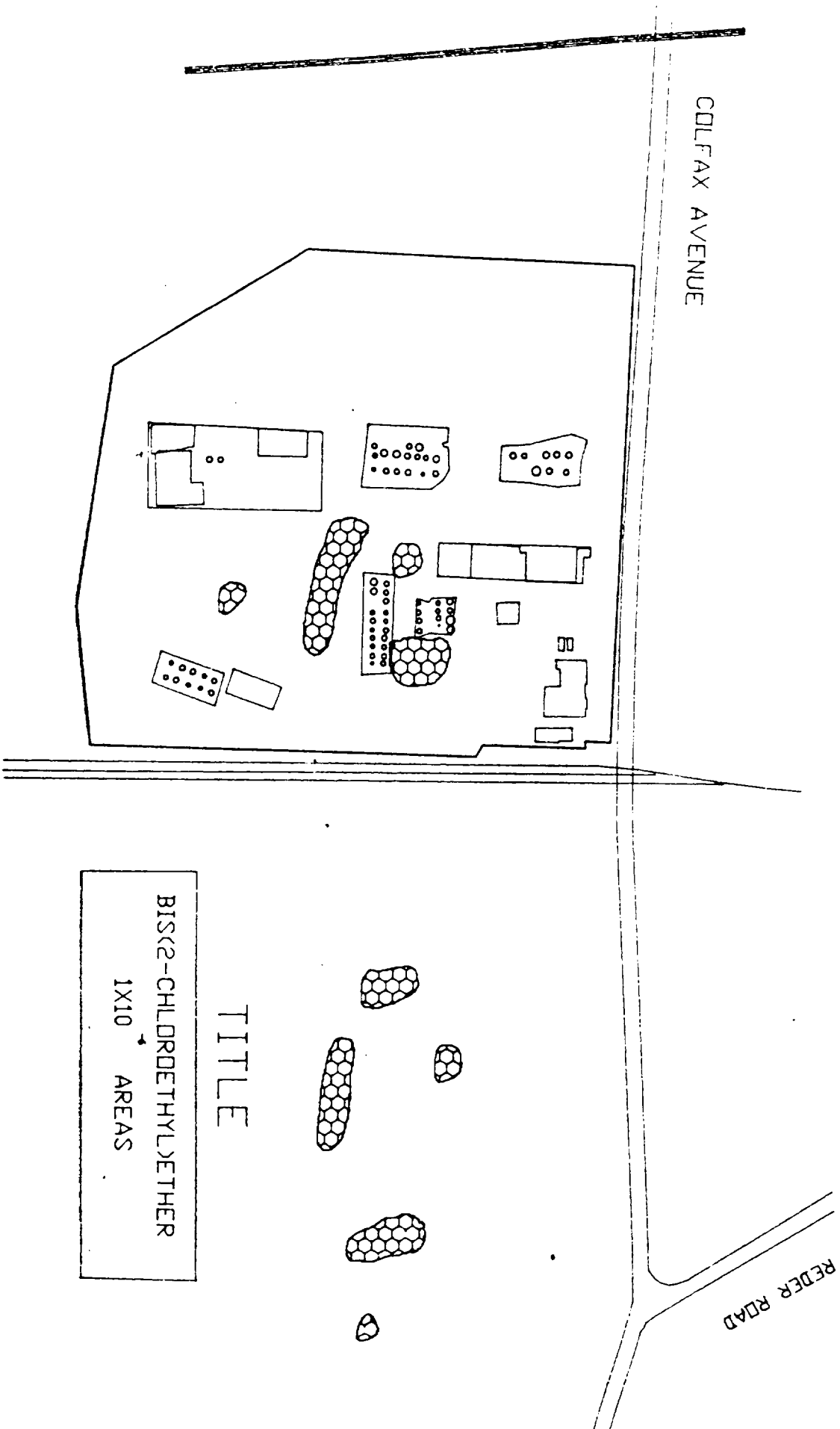


FIGURE 4

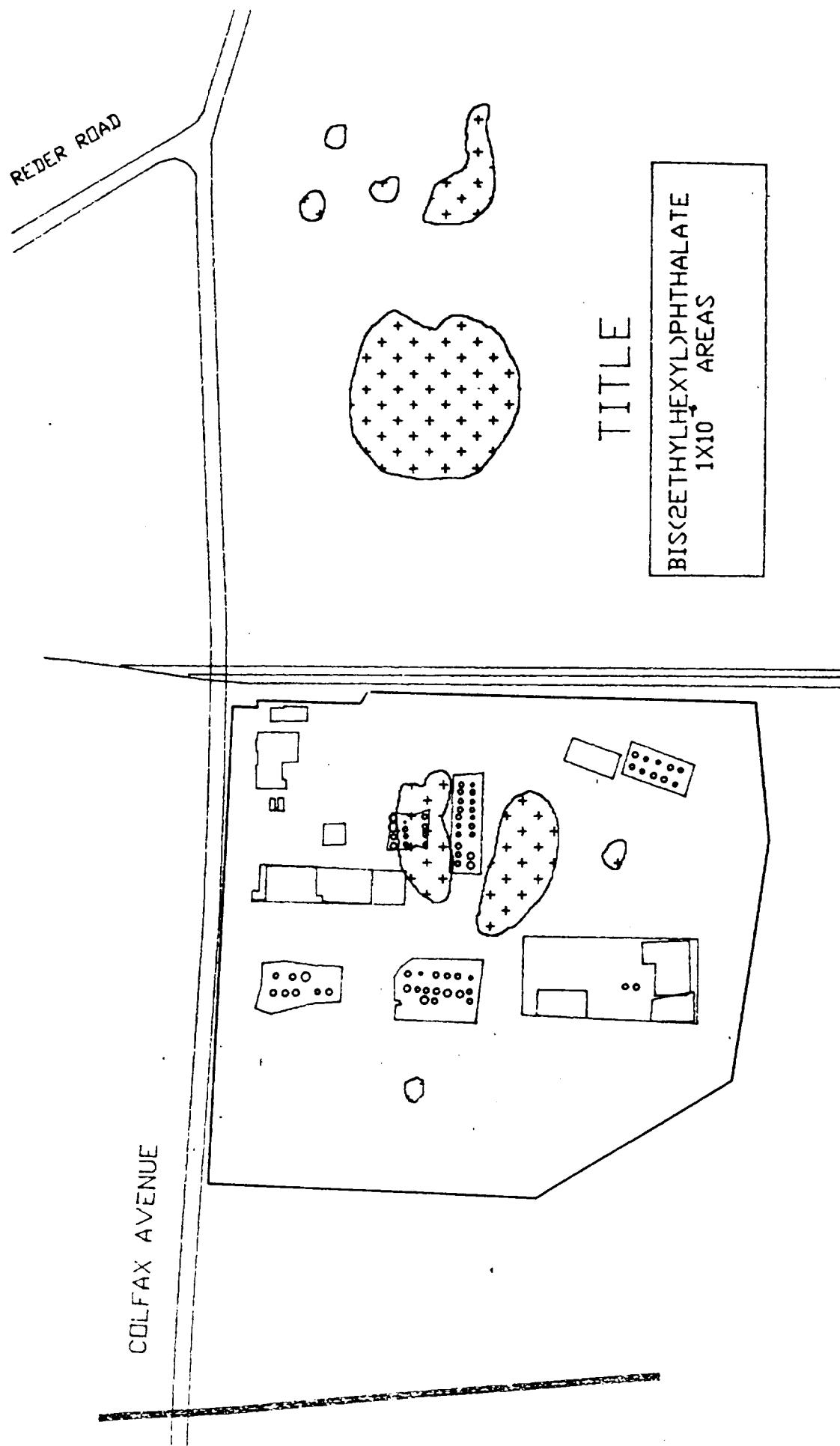


FIGURE 5

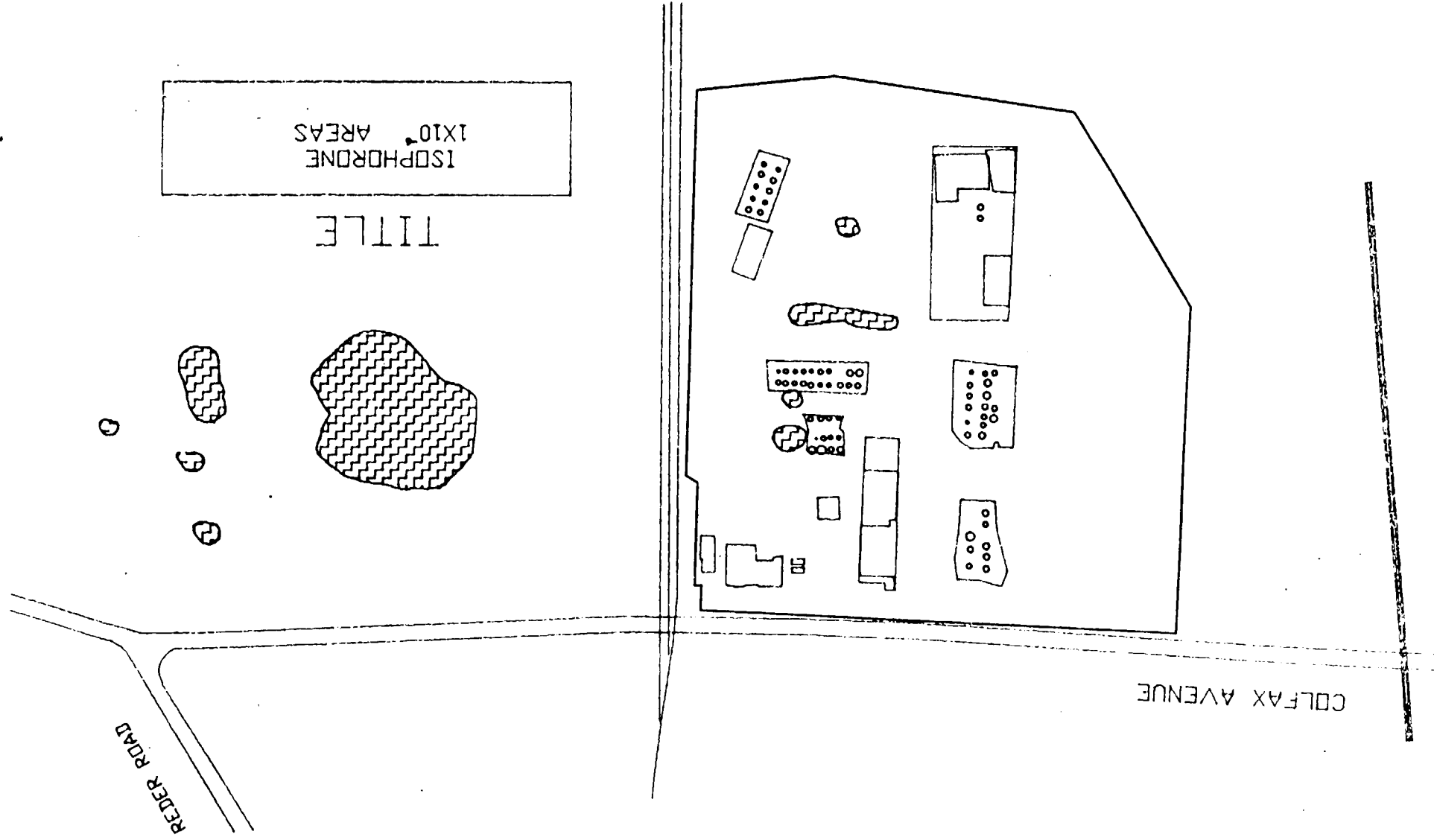
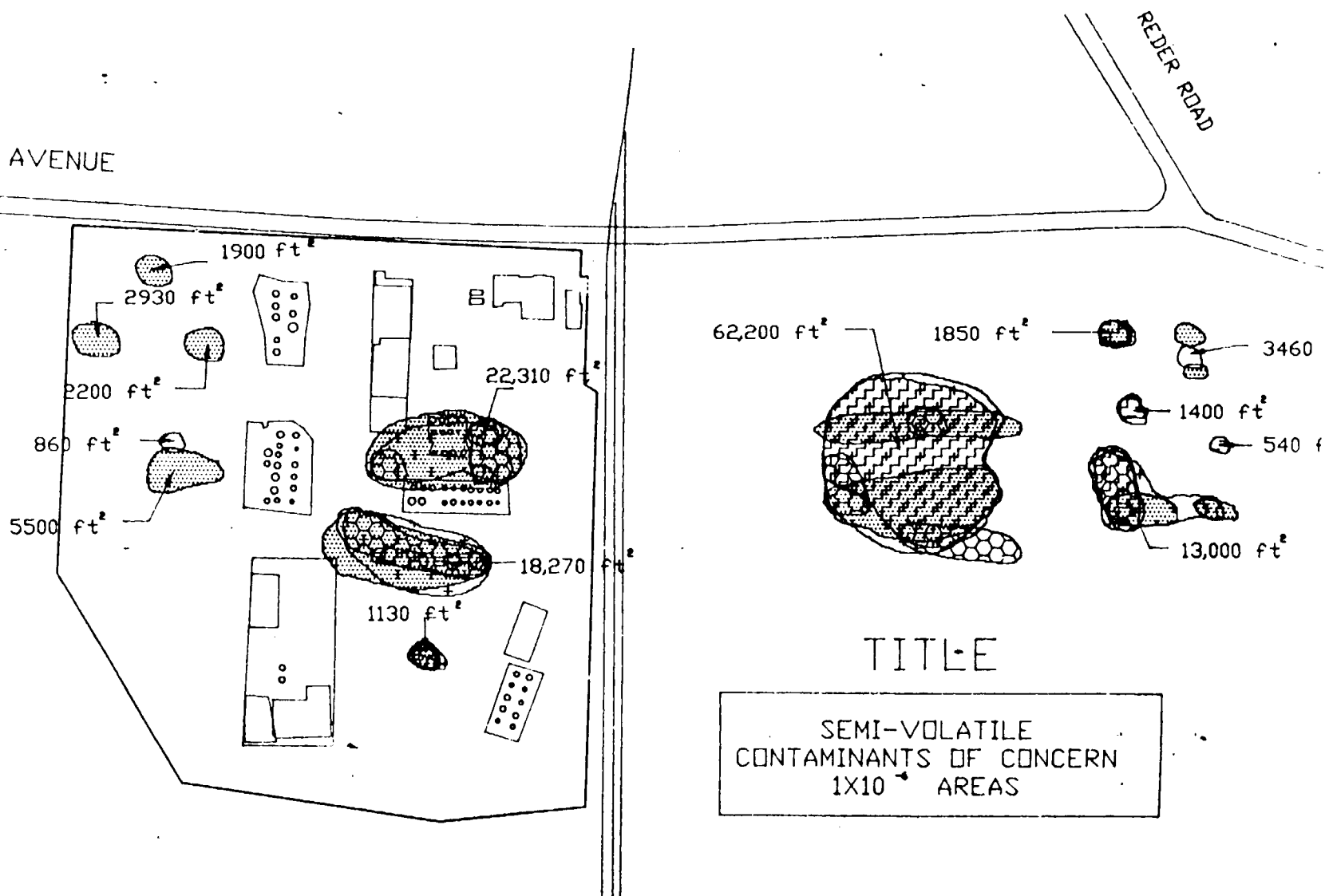


FIGURE 6



Attachment 2
U.S. EPA Specific Listing of ARARs
American Chemical Services Feasibility Study Comments

The following ARARs are being forwarded for inclusion into specific areas of the Feasibility Study Report. Many of these ARARs may already be included in the ARARs listings in the FS Report and many may not. In all cases, specific ARARs which may be problematic (as in the use of the Hammond POTW) should be specifically mentioned in the appropriate discussions on ARARs in the detailed analysis. In all cases, this list of ARARs should be checked against those already existing in the report and the listing in the report updated accordingly. IDEM ARARs are included separately as Attachment 3.

Water Pollution Control ARARs

1. 40 CFR Part 122.42(b), National Pollutant Discharge elimination System Permit Regulations - Requires notification of issuing authority of re-evaluation of POTW pretreatment standards (It should be noted that in the event that the POTW does not have a local limitation for a particular pollutant found in the leachate from this Superfund site, it must evaluate its local limitations, and develop such a limitation as necessary to protect the POTW from interference, pass through, or inhibition from that discharge).
2. 40 CFR Part 403.5, NPDES National Pretreatment Standards, discharge to a POTW must not interfere, pass through untreated into the receiving waters, or contaminate the sewage sludge.
3. 40 CFR Part 403.8(f), NPDES Pretreatment program requirements for POTWs.

It must be noted that approval must be obtained from the U.S. EPA, Water Division prior to discharge to the Hammond Sanitary Districts POTW due to poor compliance history and pending enforcement actions.

The following ARARs apply specifically to the collection and discharge of groundwater and leachate to surface waters near the site.

4. 40 CFR Part 122.44 NPDES Permit Regulations - Establishing limitation, standards, and other NPDES permit conditions, including Federally approved State water quality standards.
5. 40 CFR Part 122.44(a), NPDES Permit Regulations - Best Available Technology (BAT) for Toxic and non-conventional wastewaters or Best Conventional Technology (BCT) for conventional pollutants.

6. 40 CFR 122.44(b), NPDES Permit Regulations - Other Effluent Limitations and Standards requirements under sections 301, 302, 303, 307, 318, and 405 of the Clean Water Act (CWA).
7. 40 CFR Part 122.44(d), NPDES Permit Regulations, Water Quality Standards and State Requirements - Water Quality Based Effluent Limitations (WQBEL). Any requirements in addition to or more stringent than promulgated effluent limitations and guidelines or standards under sections 301, 304, 306, 307, 318, and 405 of the CWA.
8. 40 CFR Part 122.44(e), NPDES Permit Regulations, Technology-Based Controls for toxic pollutants, Discharge limits established under paragraphs (a), (b), or (d) of 40 CFR Part 122.44 must be established for toxics to be discharged at concentrations exceeding levels achievable by the technology-based BAT/BCT standards.
9. 40 CFR Part 122.44(l), NPDES Permit Regulations - Requires monitoring of discharges to ensure compliance.
10. 40 CFR Part 122.21, NPDES Permit Regulations - Permit application must include a detailed description of the proposed action including a listing of all required environmental permits.
11. 40 CFR Part 125.100, NPDES Permit Regulations - The site operator must include a detailed description of the proposed action including a listing of all required environmental permits.
12. 40 CFR Part 131 - States are granted enforcement jurisdiction over direct discharges and may adopt reasonable standards to protect or enhance the uses and qualities of State surface water bodies.
13. 40 CFR Part 136.1-136.4 - Requires adherence to sample preservation procedures including container materials and sample holding times.

ARARs furnished by the Indiana Department of Environmental Management (IDEM) are provided as a separate attachment to this letter.

Attachment 3



INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

105 South Meridian Street
P.O. Box 6015
Indianapolis 46206-6015
Telephone 317/232-8603

June 6, 1991

Mr. Robert Springer RA-14
U. S. EPA Region V
230 South Dearborn
Chicago, IL 60604

Re: Applicable, Relevant and
Appropriate Regulations, American
Chemical Services Site.

Dear Mr. Springer:

In response to your request for applicable, relevant and appropriate regulations (ARARs) for the American Chemical Services site in Griffith, the staff of IDEM have reviewed the alternative Apray Document for the American Chemical Services site. I am enclosing the evaluation and comments on the ARARs received from IDEM's offices of Air Management, Water Management, Solid and Hazardous Waste Management along with comments solicited from the Indiana Department of Natural Resources.

The reviews centered around the tables provided in the document, which listed potential ARARs. Many of the comments are presented as amendment to those tables.

The evaluations provided are general in nature and are designed to provide the basic framework from which a recommended alternative can be developed. Once a suitable alternative has been selected, the site and remedy specific ARARs will be provided to insure that all regulatory requirements are met during the remedial design phase. Detailed information such as emissions limitations or discharge limits cannot be provided without specific engineering design details.

We appreciate your attention to these Indiana requirements. If you have any questions, please do not hesitate to call me.

Sincerely,

Kathy Prosser
Commissioner

APPLICABLE, RELEVANT, AND APPROPRIATE REQUIREMENTS
AMERICAN CHEMICAL SERVICES SITE
GRIFFITH, IN

OFFICE OF AIR MANAGEMENT

Any of the proposed remedial options which have the potential to emit air pollutants may be subject to Air Pollution Control Board Rules as found in Title 326 of the Indiana Administrative Code. Applicable rules may include the following:

- 326 IAC 2-1, Permit Review Rules
- 326 IAC 4-2, Incinerator Rules,
- 326 IAC 6-4 and 6-5, Fugitive Dust Rules, and
- 326 IAC 8-1, Volatile Organic Compound Rules.

326 IAC 2-1

A Permit Application should be completed pursuant to Rule 2-1 for any facility which has the potential to emit air pollutants. There are special forms for air strippers and incinerators. This information is required for a technical review of the proposed project in order to identify applicable rules, determine if air pollution control equipment is needed, and establish allowable emission limits.

The OAM permit review process involves an air toxins screening to estimate the potential impact on human health. Rule 2-1-3 allows the Commissioner the authority to impose such conditions on the permit as necessary to ensure that the public health will be protected.

326 IAC 4-2

Incineration emissions are regulated under Rule 4-2. This rule limits particulate matter emissions from incinerators with maximum refuse-burning capacity of 200 pounds/hour or more to 0.3 pounds/1000 pounds of dry exhaust gas. Particulate matter emissions from incinerators with a burning capacity less than 200 pounds/hour are limited 0.5 pounds/1000 pounds of dry exhaust gas. A secondary combustion chamber of equivalent is required.

326 IAC 6-4 and 6-5

Fugitive dust emissions are regulated under Rules 6-4 and 6-5. Rule 6-4 limits fugitive dust which crosses the source's property line: no visible emissions are allowed and the increase in upwind/downwind total suspended particulate concentration is limited to 50 ug/m³. Rule 6-5 requires new sources to submit a fugitive dust control plan. The plan shall describe the methods

to be used to implement all Reasonably Available Control Technology (RACT) measures.

326 IAC 8-1

Volatile Organic Compound (VOC) emissions are regulated under 8-1, et al. Rule 8-1-6 requires Best Available Control Technology (BACT) for new sources with potential emissions greater than 25 tons per year.

The Office of Air Management is currently developing State air toxins rules which may be applicable to the facilities proposed for this site by the time the proposed remedies are implemented.

Attachment 1 contains forms from OAM's construction permit application which, when completed, should allow for adequate technical review of the project. Attachment 2 is a copy of Table 3-3 from the feasibility Study which has been revised to more correctly identify applicable State ARARs from the Air Program.

OFFICE OF SOLID AND HAZARDOUS WASTE MANAGEMENT

Table 3-2

1. Within 100-year floodplain

329 IAC 3-41-9(b) would be required for any facility acting as a TSD under RCRA to prevent washout of any hazardous wastes by a 100-year flood.

Table 3-3

Table 3-3 should be corrected as follows.

Page 1, line 2. Delete ozone, replace with Volatile Organic Compounds. Delete 3261 TC -1-4-1, replace with 3261 AC 1-3-4.

Page 1, line 10. (Air emissions of VOC's) add "and particulate matter". Delete 3261 AC Article 8, replace with 3261 AC Article 2. Also, add a new bullet, "BACT required for new VOC sources greater than .25TPY", "3261 AC 8".

Page 2, bottom of page. Add "New Source Performance Standards". "Tanks with storage capacity greater than 40m3 (10,567 gallons) storing liquid with vapor pressure greater than 3.5 kpa (0.51 PSI)" "3261 AC 12, 40 CFR 60 Support K6"

Page 4, fourth bullet from the bottom, add the Indiana Rule Cite for "control wind dispersal of particulates", "3261 AC 6-4 and 6-5".

Page 5, Excavation. Add 3261 AC 6-4 and 6-5 which regulator control of dispersal of particular.

Page 6, Incineration. The Prerequisites of Applicability of 3621 AC 4-2 are: Incinerators with burning capacity greater than 200 lbs./hr. The requirements are: Particulate Matter emissions limited to 0.3 lbs/ 1000 lbs. dry exhaust matter and particulate matter emissions for incinerators with burning capacities less than 200 lbs./hr limited to 0.5 lbs/ 1000 lbs. dry exhaust gas.

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Page 6, Incineration, fourth bullet. Under Prerequisites of Applicability (air emissions. . . lead), replace "ozone" with "Volatile Organic Compounds".

1. Air Emission from On-Site Treatment Operations

The state is not currently authorized for 40 CFR 264 Subpart AA & BB, but will probably adopt the rule by September 1991. The rule would be required for storage or treatment process vents or equipment leaks.

2. Closure with Post-closure Care

329 IAC 3-46 - All RCRA closures must meet the closure requirements and the closure performance standard under 329 IAC 3-46-2. Post-closure care of a unit must continue for thirty (30) years after the completion of closure and includes groundwater monitoring and maintenance of the waste containment system.

329 IAC 3-45 - The groundwater monitoring requirements would apply to post-closure.

3. Closure with no Post-closure Care (e. g. Clean Closure)

329 IAC 3-46 - All RCRA closures must meet the closure requirements and the closure performance standard under 329 IAC 3-46-2. All contaminants (including contaminated soil) must be removed. The closure should eliminate the need for further maintenance and control. Health-based standards may be used to demonstrate clean closure.

4. Hazardous Waste Generation, Storage and Off-Site Disposal

329 IAC 3-7 - applies to generators of hazardous waste.
329 IAC 3-8 - manifest requirements.
329 IAC 3-9 - transporting and accumulation time.

5. Hazardous Waste Tank Storage

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329 IAC 3-34 and 329 IAC 3-49. The standards for new tanks must be met. The tank construction materials must be compatible with the waste to be stored or treated. The tanks should have secondary containment to prevent the release of hazardous wastes. The tank must be inspected daily. The tank should be closed in accordance with 329 IAC 3-49-8.

40 CFR 268.50. The state is not currently authorized for CFR 268.50, but the rule would be applicable when such storage occurs beyond one year. The owner/operator bears the burden of proving that such storage is solely for the purpose of accumulating sufficient quantities to allow for proper recovery, treatment, and disposal.

6. Hazardous Waste Container Storage

329 IAC 3-43 and 329 IAC 3-48. Containers must be maintained in good condition and be compatible with the waste stored or treated. All containers must be kept closed and handled in a way which avoids leaks, spills and ruptures. Weekly inspections are required to detect leaks and potential deterioration. A containment system capable of containing 10% of the waste stored is required. The containment must be free of cracks/ gaps and able to contain leaks, spills, and accumulated precipitation or other liquids collected. Unless enclosed, run-on or rainwater, in the containment may be hazardous, and may need to be handled as hazardous waste.

40 CFR 268.50. The State is not currently authorized for 40 CFR 268.50, but the rule would be applicable when such storage occurs beyond one year. The owner/ operator bears the burden of proving that such storage is solely for the purpose of accumulating sufficient quantities to allow for proper recovery, treatment, and disposal.

7. Construction of New Hazardous Waste and PCB Landfill On-Site

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329 IAC 3-34 and 329 IAC 3-53. The landfill must have a liner system for all portions of the landfill. The liner system must have at least two (2) liners. The design, construction and operation must maintain the run-on and prevent flow onto the landfill. A monitoring and inspection program must be maintained. The landfill must be closed in accordance with 329 IAC 3-53-5.

40 CFR 268. The state is not currently authorized for 40 CFR 268 rules pertaining to the TCLP requirements, but the rules would be applicable.

329 IAC 3-45. The groundwater monitoring requirements would apply to the landfill.

Excavation

329 IAC 3-46. The closure rules as stated in item 2 and 3 would apply.

40 CFR 268. The State is not currently authorized for 40 CFR 268, but the rule would be applicable for waste transferred to a new location.

9. Incineration of Hazardous Waste and PCB's

329 IAC 3-34 and 329 IAC 3-54. The waste must be analyzed and the incinerator must be permitted and meet the Performance Standard of 99.99% DRE. All residues, ash scrubber waste and sludge must be disposed of as hazardous waste. The incinerator must be monitored for various parameters and utilize an automatic waste feed cut-off system.

10. Land Treatment

329 IAC 3-34, 329 IAC 3-50, 329 IAC 3-51 and 329 IAC 3-52. Before a waste can be treated on or in a land treatment unit, the waste must meet the treatment standards set forth in 40 CFR 268. Surface impoundments and waste piles must

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have a liner in order to prevent any migrations of waste. Groundwater monitoring may be required under 329 IAC 3-45. Run-off of hazardous constituents must be minimized. Run-on/ run-off control and management system must be minimized. Special application conditions would apply if foodchain crops are grown in or on treatment zone. Special requirements for ignitable or reactive waste, and special requirements for incompatible wastes would apply. Special testing and location requirements for certain hazardous wastes would apply.

40 CFR 268. The State is not currently authorized for 40 CFR 268, but the rule would be applicable for land ban wastes.

11. Surface Water Control

329 IAC 3-51-2, 329 IAC 3-52-4, and 329 IAC 3-53-2. Prevent run-on and control and collect from a 24-hour 25-year storm (waste piles, land treatment facilities, landfills). Prevent over-topping of surface impoundment.

12. Treatment of Hazardous Waste or PCB's (in a unit)

329 IAC 3-50-2, 329 IAC 3-51-2, 329 IAC 3-52-4, 329 IAC 3-54-4 thru 546, 329 IAC 3-30-2. Design and operating standards for units in which hazardous waste is treated.

40 CFR 264.601 would apply to miscellaneous units however the State is not yet authorized for the rule.

13. Placement of Hazardous Waste in Land Disposal Unit

40 CFR 268 (subpart D) would apply, however the State is not yet authorized for the rule.

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Table 3-4

1. Potential TBC-RCRA health-based "action levels" for individual Appendix VIII hazardous constituents. No rules currently apply, however the July 27, 1990, Federal Register- Proposed RCRA Corrective Action Regulations should be considered.

: Office of Water Management

Table 3-2, Effluent for stream or river, add the citation "327IAC5".

Table 3-3, page 8, Best Available Technology, add the citation 327IAC5. (327IAC5 requires Best Management Practice and Best Professional Judgement where numeric effluent limitations are in feasible or the practices are reasonably necessary or where required under the Clean Water Acts.

Table 3-3, page 9, Discharge to Publicly Owned Treatment Works, second bullet. Remove "327IAC5-2-10" and "327IAC5-5-3", replace with "327IAC5-11 through 15.

Table 3-3, page 9, Discharge to Publicly Owned Treatment Works, third bullet. Citations are 327IAC5-11 through 15 and 326IAC8.

Department of Natural Resources

IC-13-2-6.1

In addition to the requirements of 13-22-2 which were included in the tables, DNR also requires registration of extraction wells that are "Significant Water Withdrawal Facilities". Forms and Requirements are attached. This rule addresses extraction wells which may impact private drinking water wells, and requires the owner of the extraction well to provide an alternative water supply to persons affected by the well.

PC/lk

Attachment 4

Optimizing Pumping Strategies for Contaminant Studies and Remedial Actions

by Joseph F. Keely

Abstract

One of the more common techniques for controlling the migration of contaminant plumes is the use of pumping wells to produce desired changes in local flow rates and hydraulic gradients. When seeking to optimize an array of pumping well locations and discharge rates, it is important to consider the effects that non-ideal aquifer conditions, well construction and demographic constraints produce. Heterogeneous and anisotropic aquifer conditions seriously complicate siting and discharge rate requirements for pumping wells because of the distorted cones of depression that result from withdrawing water in such settings. Proper screen selection, gravel pack emplacement and well development are crucial factors affecting the operational characteristics and economics of pumping wells; these factors are generally recognized, though often undervalued. The impacts that well depth and diameter, and screen length and position have on the effectiveness of pumping efforts are also often undervalued, with detrimental consequences. Perhaps the most difficult problems to overcome in designing pumping schemes, however, are posed by demographic constraints. Denial of property access, vandalism and the unpredictability of nearby water supply and irrigation pumpage tend to wreak havoc with the best of pumping strategies.

Introduction

Safe storage and disposal of hazardous wastes have become major social issues because of the discovery that many sites lack proper precautions for the prevention of soil and water contamination. Ground water contamination has received the major share of society's attention to these issues, primarily because the route of human exposure by this pathway is direct. In practical terms, this means that the level of cleanup of the damage done by contamination incidents is often dictated by social concerns (e.g. health risk). Plume stabilization by interception and control with perimeter wells, injection and recovery loops, and other

pumping schemes may be chosen as the "remedial action" appropriate for a particular plume. The affected plume may be held in place and treated, it may be held and allowed to move on after alternate public supplies have been located for downgradient water systems, it may be held in place to allow biodegradation of particular constituents, or it may be held until better treatment procedures can be devised.

Factors Affecting Pumping Strategies

Hydrodynamic control and recovery strategies vary considerably in their efficiencies. Besides the obvious need to choose the well locations and flow rates carefully, a number of other considerations demand attention (Figure 1). Non-ideal aquifer conditions are a reality for virtually all real-life situations; heterogeneity is the rule rather than the exception. Three-dimensional anisotropy, as expressed by the vertical vs. horizontal hydraulic conductivity ratio, is a near certainty for most strata. Less visibly pronounced, yet almost as prevalent, is an expressed anisotropy in the horizontal plane of many strata. These commonplace non-ideal aquifer conditions complicate our perception of where a given plume can go (Fetter 1981) under both natural flow conditions and remedial action pumping schemes. The preferential flow paths that are created by buried lake beds, glacial outwash gravels, streambeds, coastal deposits and the like cannot be delineated without expensive and time-consuming field tests. Likewise, it is nearly impossible to accurately predict the magnitudes of distortion in the cones of depression created by wells pumping from heterogeneous, anisotropic aquifers.

Variations in the properties of the fluid in an aquifer, particularly the solution density, also can significantly affect the behavior of contaminant plumes (Jorgenson et al. 1982). Immiscible plumes with lower density than that of the native ground water will float at the surface of the saturated zone, traveling along the same general gradient, but traveling

at a different rate than the underlying ground water. Immiscible plumes with greater density than that of the native ground water will sink through the ground water, losing small but significant amounts of low solubility constituents as they move. Miscible plumes of any density, by definition, mix intimately with native ground water. The duration of time required to achieve a specific dilution by this mixing changes markedly, however, and is generally inversely related to the density. For most situations, the greater the density, the shorter the mixing period. The exception to this general rule would be the case of a large volume of highly dense, miscible fluid penetrating a shallow aquifer quickly enough to reach bedrock in a relatively undisturbed form.

Considerations

Non-Ideal Aquifer Conditions:

- Heterogeneity
- Anisotropism
- Variable density

Well Construction Effects:

- Partial penetration
- Partial screening
- Incomplete development

Anthropogenic Influences:

- Property access
- Vandalism
- Unknown pumpage/injection

Other Factors:

- Physiochemical attenuation
- Biological transformations
- Operational failures

Figure 1. General considerations for optimizing pumping strategies

These complexities work against us if we are ignorant of them. Working up an appropriate recovery system for a contaminant plume can be compared to designing an oil production system. What you get out depends directly on what you put in—up to a point. Where that break-even point comes is hard to say, given unknowns like the source strength and timing, and immeasurables like the dollar value of additional cancer victims. What is abundantly clear, however, is that there is a substantial minimum for serious play. One does not blithely draw up plans to pump and treat a plume until considerable manpower and funds are expended to obtain information on the natural flow direction, gradient and velocity. The question is usually one of how much to spend to reach some desired level of detail; the level of detail is set by social concerns.

This seems to be logical application of technology for social need, but the logic may be shortsighted. If social concerns (based on preliminary evaluation of a contaminant incident) are minimal, there is no guarantee that such social concerns are appropriate. Additional studies, which could delineate preferential flow paths and quantify factors affecting contaminant behavior, might well generate findings that would justify considerably greater or lesser social concern. Quite often data from preliminary investigations are limited to samples from shallow on-site wells, which may fail to signify the potential impact of dense plumes

or seasonally-occurring leachate plumes that have moved off-site. Additionally, the preliminary investigation wells are not normally installed to a sufficient depth for appreciation of the local stratigraphic and lithologic characteristics of the aquifer.

In addition to a better understanding of where contaminants might go with the natural flow, a second powerful argument to avoid "penny-wise and pound-foolish" investigations concerns the need to provide the best information possible for targeting well locations and pumping strengths in remedial actions. The occurrence of specific heterogeneities can be used to advantage by locating wells near low permeability clay units to generate greater drawdown for a given pumping rate. Likewise, knowledge of the direction of the principal horizontal axis in anisotropic strata can help to maximize the arrangement of the "troughs of depression" for wells to be located in such settings; knowledge of the magnitude of vertical anisotropy can help determine the amount of water pumped from strata containing contaminants vs. the amount of "clean" water from the other strata open to the well.

This latter factor, vertical anisotropy, leads to examination of some of the more controllable items to be considered in optimizing pumping strategies—well construction effects. For example, the impact that partial penetration of a fully screened pumping well can have on the estimate of potential for contamination of a water supply or on the effectiveness of a remedial action scheme is tremendous (Saines 1981). The effect is to cause exaggerated drawdowns near the well. The magnitude of the effect is inversely dependent on the degree of penetration of the well into the aquifer, being greatest for slight penetration. Naturally, partial screening of a fully penetrating well results in the same effect: greater drawdown for a given pumping rate as compared with a fully screened, fully penetrating well.

Again, knowledge of these factors can be used to enhance a pumping scheme that is, for example, designed to maintain hydrodynamic control of a plume at the lowest possible level of pumpage. Lack of appreciation of these well construction effects can result in poor estimates of potential contaminant impacts on supply wells and in poorly designed remedial action schemes. Another effect worthy of mention is that generated by well development practices. If a well is properly developed, the drawdown measurable inside the well will agree with the level projected by close observation wells. More often, however, a well is not perfectly efficient because the well development procedures were not adequate to remove drilling fluid fines and locally disturbed aquifer material resulting from the drilling process. These materials lower the permeability of the gravel pack and formation immediately adjacent to the well. The greater the degree of well inefficiency caused by lack of proper development, the greater the amount of non-productive drawdown inside the well; this means that the well may never be able to pump at design capacity without risk of running dry, and it means increased operating expense due to the additional pump lift required. What it may also portend, for seriously inefficient wells, is that certain strata penetrated by the well may be effectively sealed by drilling mud or by natural clays that were smeared over the borehole face by the actions of the drilling operation. Such "sealed off" strata may carry the bulk of the contaminants, resulting in poor recovery of the plume.

Some of the most significant, though less controllable, factors that should be considered when optimiz-

ing pumping strategies concern direct anthropogenic influences: denial of property access, vandalism and unknown pumpage all tend to wreak havoc with the best laid plans. Bedient et al. (1984) describe efforts to delineate a plume of contaminants migrating under a residential area from an abandoned wood creosoting plant in Conroe, Texas:

"Several wells exist in the general flow direction, but not directly downgradient from the waste pit locations. Access was not granted for installing monitoring wells... Approximately 50 percent of the chloride plume has been defined since the monitoring well network is incomplete at this time... Completion of the monitoring well network is needed to capture the center of the contaminant plume. This will require more wells downgradient on land that has not previously been accessible for investigation."

The granting of property access during investigations of ground water contamination incidents in populated areas is no trivial matter. One typically finds it necessary to contact not only homeowners and landlords for private property access, but also to negotiate with company engineers, vice presidents and attorneys for commercial property access. It is quite normal for such negotiations to be involved and protracted as city councils, educational boards, corporate headquarters and other bureaucratic entities are asked to concur in signing access agreements containing provisions deemed necessary to ensure against incurred liability and potential damage.

The role played by unknown pumping and/or injection wells operating near a remedial action pumping system is subtle but far-reaching. Such unknown stresses can significantly distort the flow field and render remedial actions ineffective. Projections on plume movement made during an investigation of a ground water contamination incident would also be in error if unknown wells are causing distortion in the flow field; both the direction and the speed of the plume could be dramatically altered. The reason for the subtlety of the effects of many such wells is that their cyclic, seasonal or on-demand pumping schedules allow them to be detected only by continuous recording of water level changes at numerous points around the zone of interest. Since aquifer responses at a given observation point are somewhat non-unique, merely detecting extraneous sources of drawdown does not automatically result in identification of the sources.

There are a few other important factors to consider that also affect pumping strategies. The physiochemical properties of the contaminant itself can result in a need to pump several pore volumes from each unit volume of aquifer to be decontaminated. Sorption, ion exchange and speciation changes can result in retarded movement of contaminants relative to the average velocity of the water with which they are initially associated. Biotransformation of contaminants may result in reaction products (daughter products) that are of greater or lesser toxicity, mobility and persistence—in other words, uncertain contaminant behavior. Unlike the aquifer properties of storage coefficient, saturated thickness and hydraulic conductivity, which can be readily determined, the current state-of-the-science with regard to determining the potentials for physiochemical attenuation and biotransformation is not up to the level of routinely providing reliable answers on a site specific basis.

Finally, an obvious but often overlooked consideration involved in optimizing pumping strategies is the need to develop adequate contingencies for operational failures. This means some intentional overdesign for reserve capacity, total redundancy of key wells and electronic controls, backup power systems and so on. It also means bonding or insurance against unforeseen catastrophes so that as little downtime is expended as possible. It may also mean that an escrow account or trust fund must be established to provide the necessary capital for replacement of burned-out or inadequate pumps, deepening or abandonment of existing wells, or drilling of additional wells.

Capture Zones vs. Zones of Pressure Influences

Keely and Tsang (1983) introduced the term "capture zone" to describe that portion of the aquifer affected by pumping which actually yields water to the well. They have shown that the capture zone is generally much smaller than the zone of pressure influence because a balance is achieved, under steady-state conditions, between the pull of water back toward the well from its downgradient side and the tendency of the natural flow system to move on further downgradient. Figure 2 is a series of four idealized illustrations that present conceptualizations of how the size of the capture zone changes, relative to the zone of pressure influence/cone of depression, as the local gradient is increased. In Figure 2A the well is pumping from a stagnant aquifer, indicated by the flat pre-pumping surface, overlaid on the theoretical cone of depression that would occur during pumpage. For stagnant aquifer conditions, the capture zone is everywhere identical to the zone of pressure influence and flow is radial into the well. As the successive diagrams indicate, however, non-stagnant aquifer conditions lead to smaller capture zones (Figures 2B to 2D).

The slopes of the pre-pumping surfaces are overlaid on the theoretical drawdown cones in each frame of Figure 2 to emphasize the interaction of the natural flow system with the pumping stress to yield a capture zone smaller than the zone of pressure influence. There is no intention to show the net surface resulting from pumpage by subtracting theoretical drawdown values from pre-pumping water elevations. These sketches do have the cosmetic drawback of showing crossing water level lines/curves, but the point is to illustrate the individual components of the net surface (cross-sectional view) and how they interact to yield a capture zone (three-dimensional view).

The flow lines generated by pumping a well from an idealized aquifer (homogeneous, isotropic, constant density, etc.) under different natural flow conditions are shown in Figure 3. In Figure 3 a well pumping $1,000\text{m}^3/\text{day}$ from a 10m thick aquifer having a porosity of 0.10 and a hydraulic conductivity of $100\text{m}/\text{day}$ has uniform radial flow under stagnant aquifer conditions (e.g. natural flow velocity equal to zero). When a mild hydraulic gradient (0.0001) is imposed on the same system (Figure 3B), the resulting natural flow velocity ($0.1\text{m}/\text{day}$) is insufficient to significantly affect the flow lines, and uniform radial flow is nearly maintained. With a more moderate hydraulic gradient (0.001), the resulting natural flow velocity ($1.0\text{m}/\text{day}$) is sufficient to sweep away many of the flow lines and the capture zone is clearly evident (Figure 3C). Where a steep gradient (0.01) is present, the capture zone

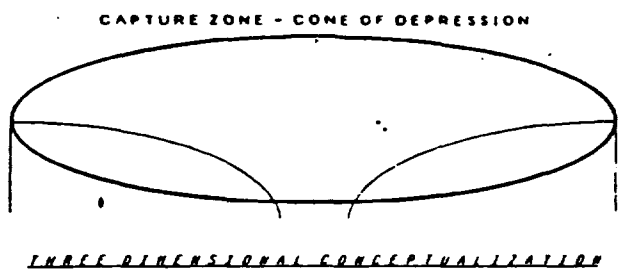
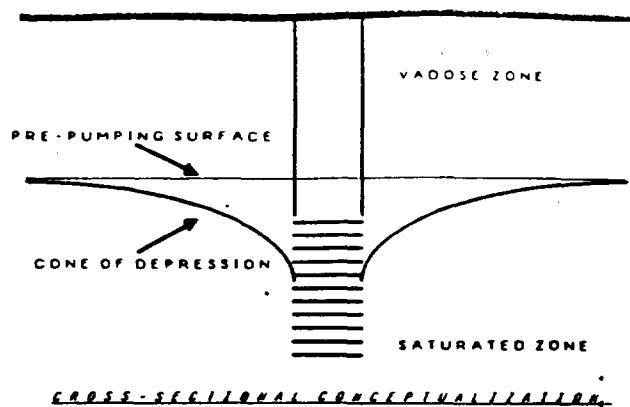


Figure 2A. Stagnant aquifer conditions

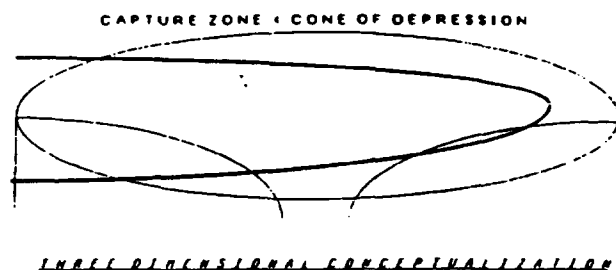
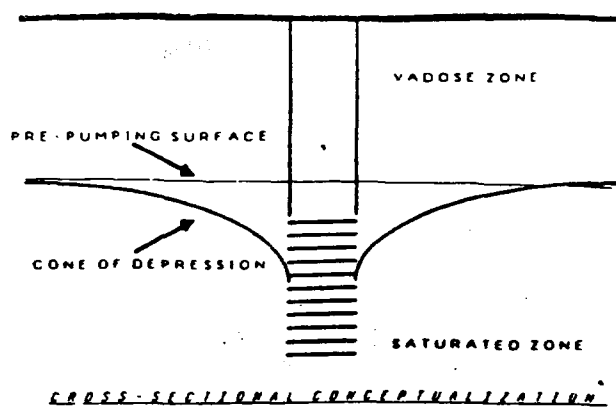


Figure 2B. Mild natural gradient

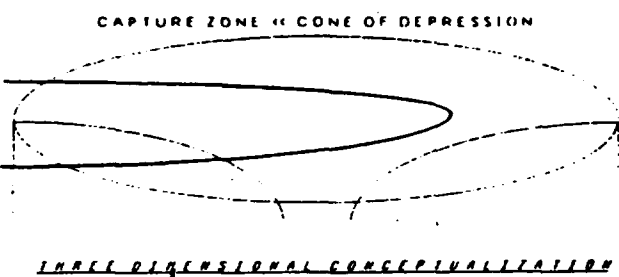
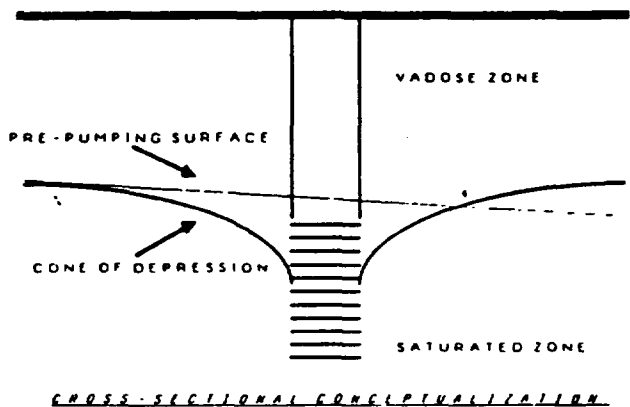


Figure 2C. Moderate natural gradient

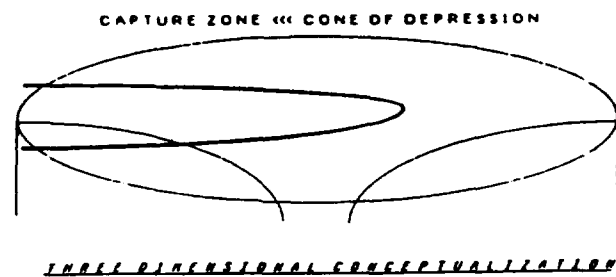
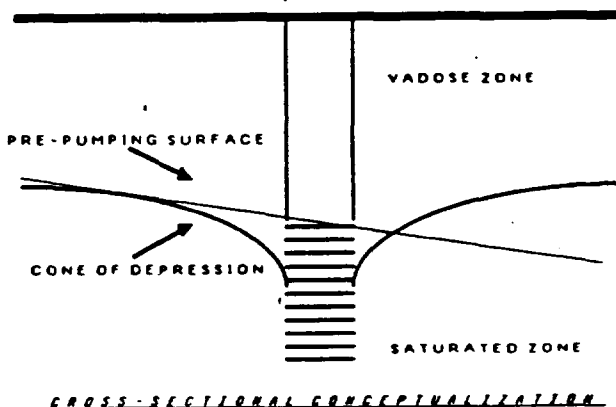


Figure 2D. Steep natural gradient

Figure 2. Cross-sectional and three-dimensional conceptualizations of capture zone vs. cone of depression

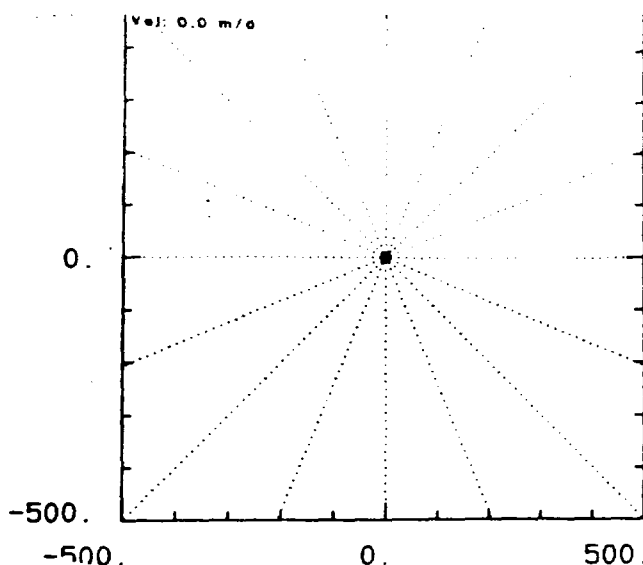


Figure 3A. Stagnant aquifer conditions

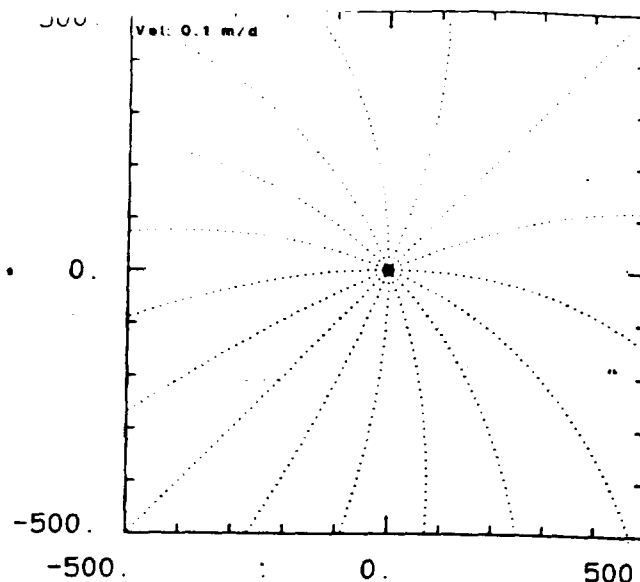


Figure 3B. Mild hydraulic gradient (0.0001)

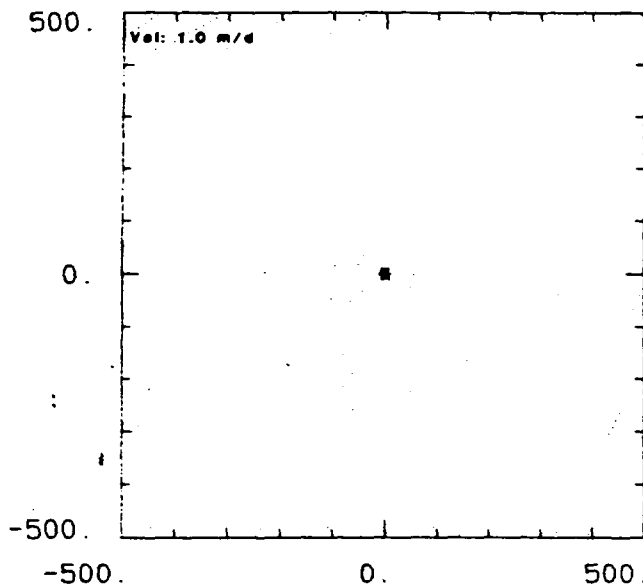


Figure 3C. Moderate hydraulic gradient (0.001)

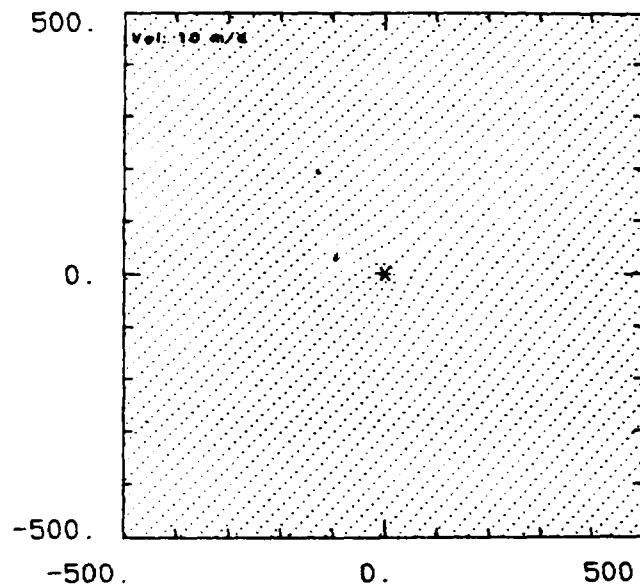


Figure 3D. Steep hydraulic gradient (0.01)

Figure 3. Flow line plots for a single well discharging $1,000\text{m}^3/\text{day}$ from an aquifer with 10m saturated thickness, 100m/day hydraulic conductivity and 0.10 porosity

NOTE: Scale is in meters and natural flow proceeds from lower left-hand corner to upper right-hand corner of each plot at the velocity indicated.

influence (Figure 3D).

Comparing Pumping Strategies

A typical use of pumping schemes is to effect hydrodynamic control over a plume, either for long-term stabilization or for withdrawal and treatment. Consider extending the example illustrated by Figure 3. First, assume a line of five wells lying perpendicular to the direction of natural flow (Figure 4). Each of the five wells pumps $200\text{m}^3/\text{day}$, so that the total pumpage of the five wells is the same as that of the single well in Figure 3. Under stagnant aquifer conditions to low natural flow velocities (Figures 4A and 4B) there does not seem to be any difference in the effectiveness of the pumpage from the five wells as com-

pared with the single well case (Figures 3A and 3B). The situation changes markedly if moderate to high natural flow velocities are present, however, as depicted in Figures 4C and 4D. As the natural flow velocity increases, the capture zone of each of the five wells diminishes to a point where adjacent capture zones no longer overlap and natural flow lines run on through the line of wells. By contrast, the capture zone of the single well pumping $1,000\text{m}^3/\text{day}$ does not develop holes, but does diminish in size to well below the perceived size of the leaky collective capture zone of the line of five wells.

In actuality, there is no difference between the true collective size of the capture zones generated by the

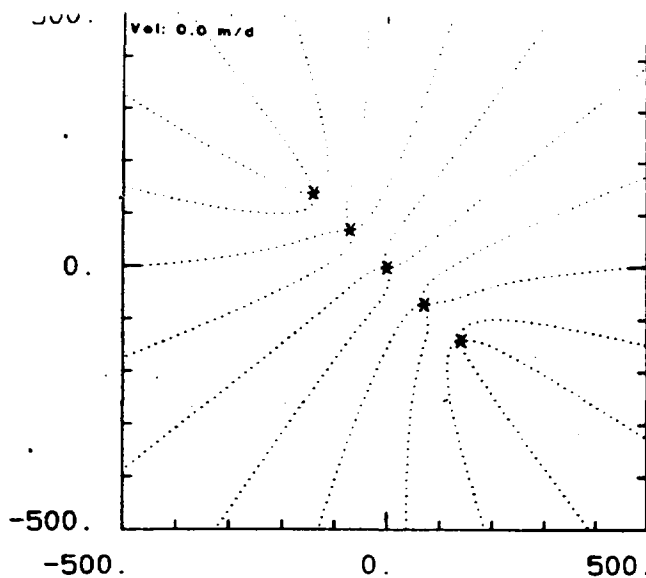


Figure 4A. Stagnant aquifer conditions

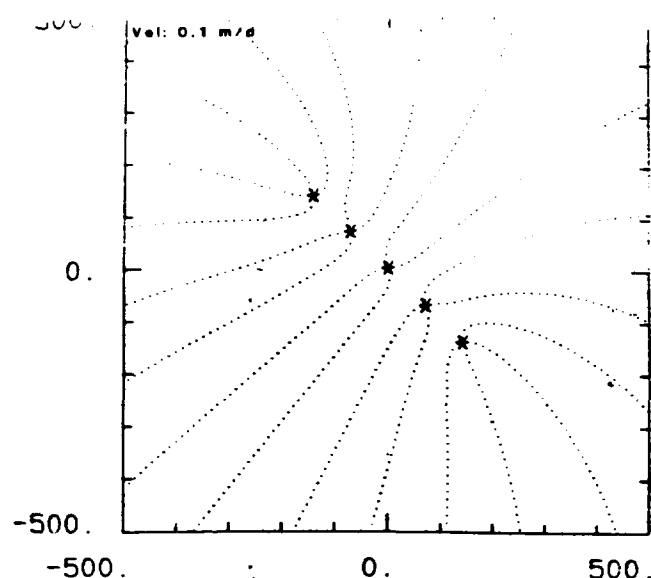


Figure 4B. Mild hydraulic gradient (0.0001)

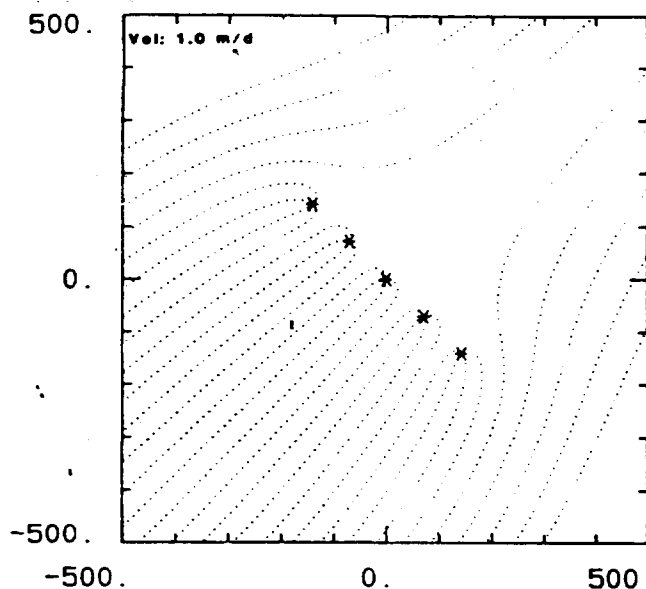


Figure 4C. Moderate hydraulic gradient (0.001)

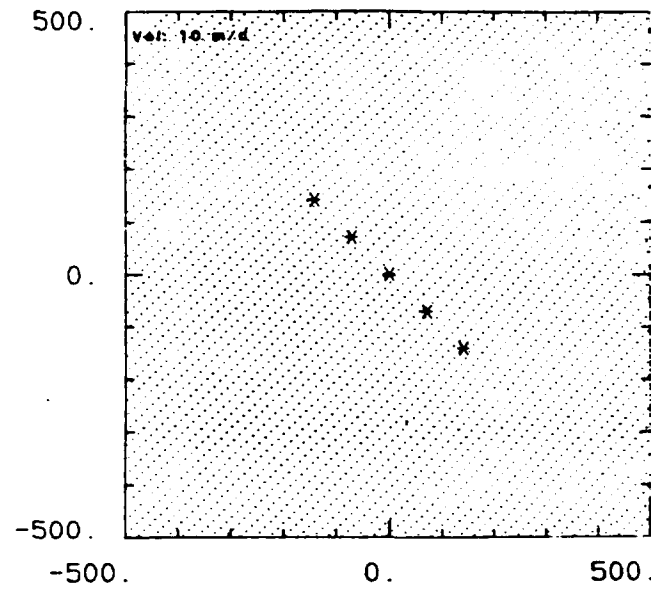


Figure 4D. Steep hydraulic gradient (0.01)

Figure 4. Flow line plots for a line of five wells, each discharging 200m³/day from an aquifer with 10m saturated thickness, 100m/day hydraulic conductivity and 0.10 porosity

NOTE: Scale is in meters and natural flow proceeds from lower left-hand corner to upper right-hand corner of each plot at the velocity indicated.

rate well. By rearranging some of the expressions for capture zone dimensions given by Keely and Tsang (1983), it is possible to define the maximum width of the capture zone upgradient of the well as: $W_{max} = Q \div (h\phi_c V_{nat})$. Using this relationship, it is apparent that the maximum width (W_{max}) of the capture zone of a well is directly and linearly related to its flow rate (Q), and is inversely related to the natural flow velocity (V_{nat}).

For the example discussed here regarding a single well pumping 1,000m³/day, the maximum width of the capture zone is 1,000m when the natural flow velocity is 1.0m/day, and is 100m when the natural flow velocity is 10m/day. Each of the five wells in the second example discussed pumps at a flow rate equal to one-fifth the flow rate of the well in the first example

(200m³/day), and each, therefore, has a capture zone the maximum width of which is one-fifth that of the single well (200m). Hence, by comparing Figure 3 with Figure 4, it is seen that the way in which the total pumpage is distributed does directly affect the distribution of the capture zone(s), but does not affect the magnitude or total area of the capture zone(s). Also to be seen in Figures 3 and 4 is that increasing the natural flow velocity estimate can have a dramatic impact on the effectiveness of the pumping strategy. Given the order-of-magnitude uncertainty so often associated with hydraulic conductivity estimates, it is not surprising that many seemingly acceptable remedial action schemes are doomed to fail miserably.

A more complicated example provides further illustration of these points. Assume that we have the same

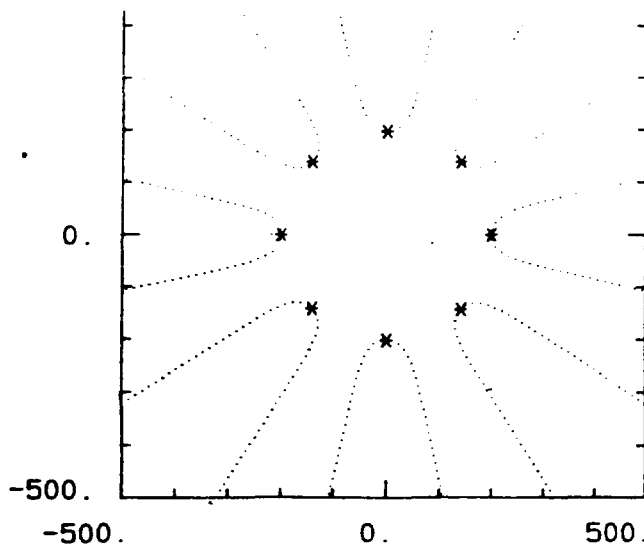


Figure 5A. Stagnant aquifer conditions

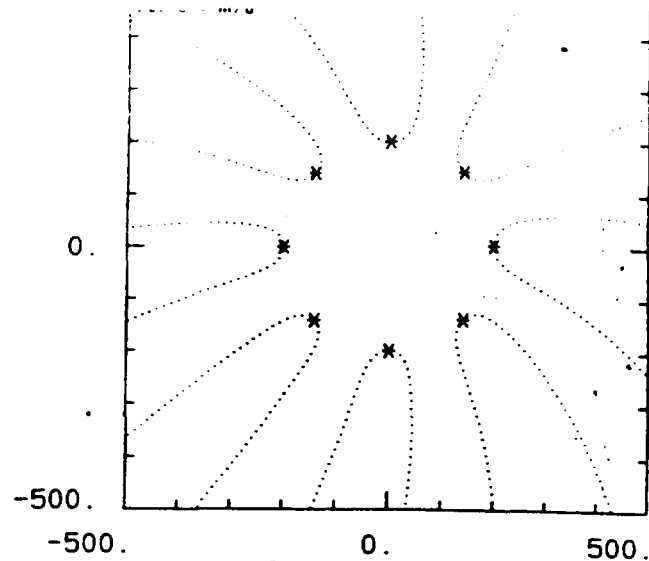


Figure 5B. Mild hydraulic gradient (0.0001)

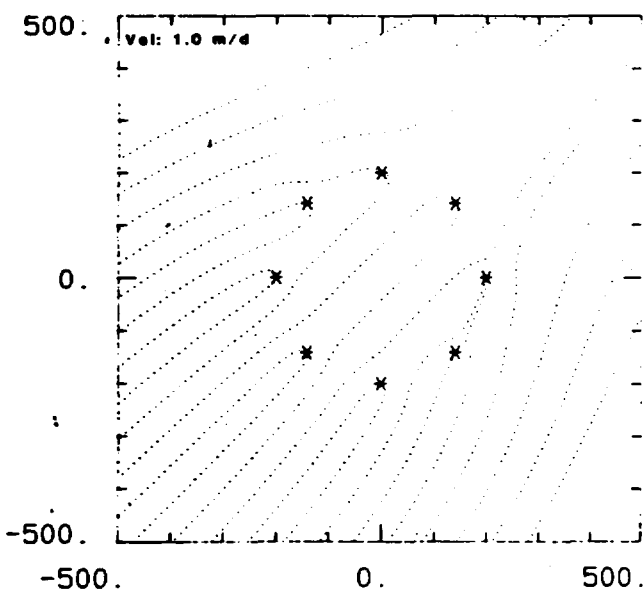


Figure 5C. Moderate hydraulic gradient (0.001)

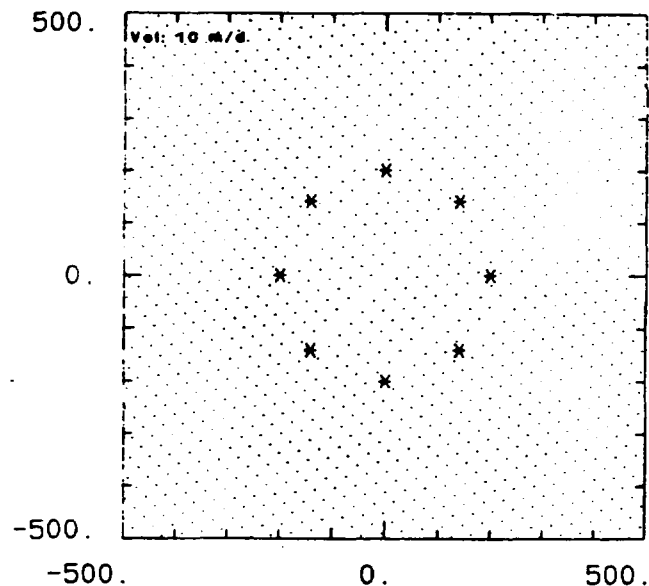


Figure 5D. Steep hydraulic gradient (0.01)

Figure 5. Flow line plots for a circle of eight wells, each discharging $125\text{m}^3/\text{day}$ from an aquifer with 10m saturated thickness, 100m/day hydraulic conductivity and 0.10 porosity

NOTE: Scale is in meters and natural flow proceeds from lower left-hand corner to upper right-hand corner of each plot at the velocity indicated.

aquifer conditions and total pumpage limitation ($1,000\text{m}^3/\text{day}$) as the preceding examples. We will distribute the pumpage uniformly by pumping each of eight wells at $125\text{m}^3/\text{day}$. The eight wells are evenly spaced around a circle of 200m radius. We are trying to hold a plume within the circle. With stagnant aquifer conditions to low natural flow velocities, the plume appears to be stable; no flow lines pass through the circle (Figures 5A and 5B). At moderate to high natural flow velocities, however, the situation is quite different; flow lines readily pass through the circle, indicating that the plume stabilization attempt has failed (Figures 5C and 5D).

A pump and treat scenario can be examined by modifying the example shown in Figure 5 to change the operation of the eight wells from pumping to

injecting and by adding a major pumping well in the center of the circle. The single pumping well will withdraw $1,000\text{m}^3/\text{day}$ from the plume. The withdrawn water will be treated and re-injected into the eight injections wells at $125\text{m}^3/\text{day}$ each. At zero to low flow velocities, the injected water flows radially toward the central pumping well, forming a closed loop for recovery and treatment of the plume (Figures 6A and 6B). At moderate to high natural flow velocities, the recovery loop is broken and an increasing amount of the injected water and the plume are swept away by the regional flow (Figures 6C and 6D). It must be emphasized that the cones of impression or depression of the wells overlap significantly for all of the multiwell examples discussed so far. Despite those overlaps, the net surface resulting from the natural gradient and the

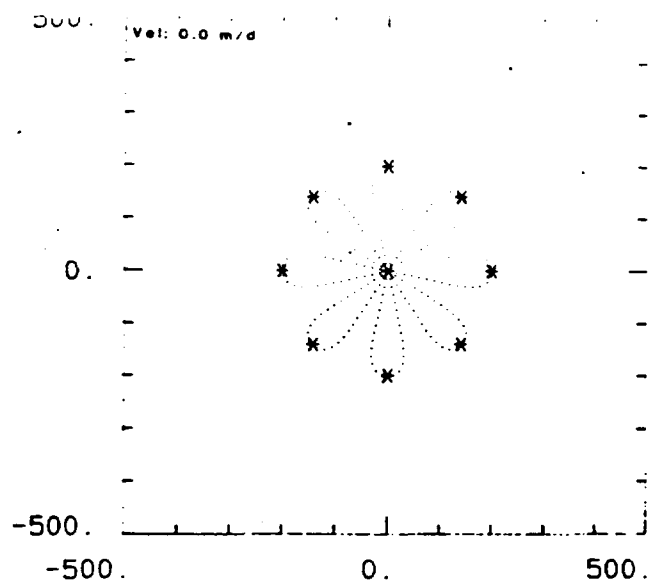


Figure 6A. Stagnant aquifer conditions

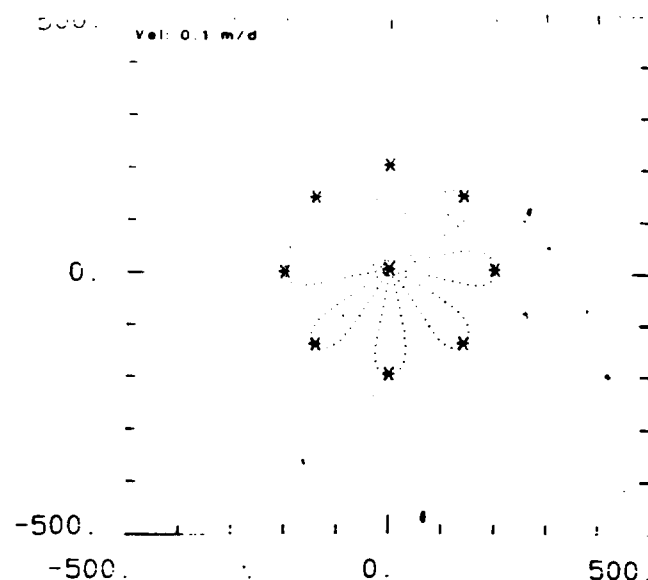


Figure 6B. Mild hydraulic gradient (0.0001)

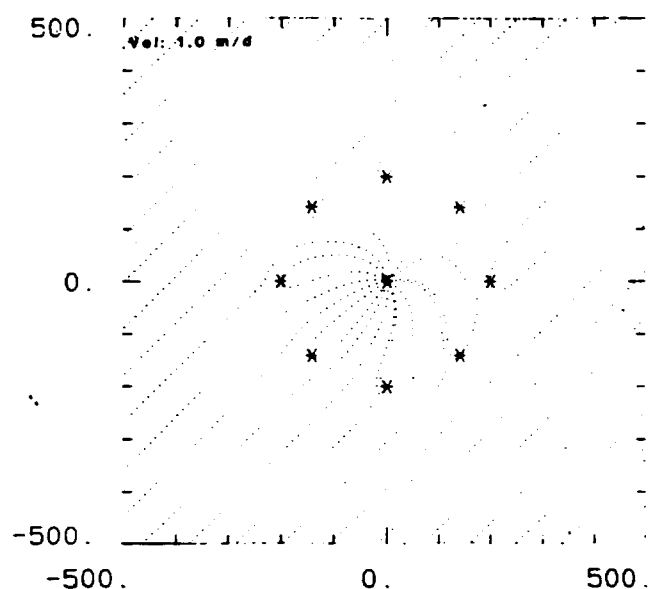


Figure 6C. Moderate hydraulic gradient (0.001)

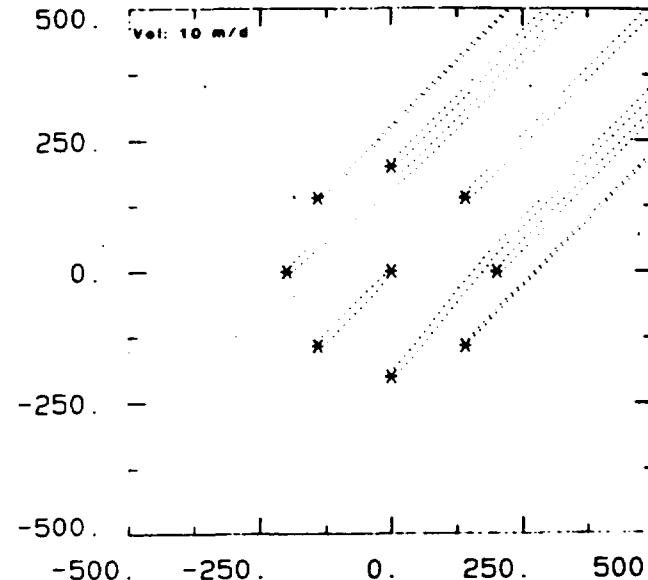


Figure 6D. Steep hydraulic gradient (0.01)

Figure 6. Flow line plots for a single well discharging $1,000\text{m}^3/\text{day}$, encircled by eight wells injecting $125\text{m}^3/\text{day}$ into an aquifer with 10m saturated thickness, $100\text{m}/\text{day}$ hydraulic conductivity and 0.10 porosity

NOTE: Scale is in meters and natural flow proceeds from lower left-hand corner to upper right-hand corner of each plot at the velocity indicated.

water level changes due to pumpage and/or injection is shaped such that the streamlines are truly as presented here. For further discussion of capture zones and velocity distribution plots, see Keely and Tsang (1983). The detailed theoretical development and source code listings for the models that were used to generate the stream line plots shown here are given in Javandel et al. (1984).

A Little More Detail

It was quite clear in each of the preceding examples that the pumping strategy began to fail as the natural flow velocities became appreciable. The tendency to fail is generally becoming evident at a natural flow velocity of $1.0\text{m}/\text{day}$ and is beyond question at a natural flow velocity of $10\text{m}/\text{day}$. Figure 7 shows that

failure of each design is certain at $5.0\text{m}/\text{day}$ as well; the point at which the flow lines break through must be at much lower natural flow velocities.

In Figure 8 the natural flow velocity has been reduced to 0.5 and $0.4\text{m}/\text{day}$ for the last two examples only. Breakthrough of the streamlines (failure of the pumping strategy) occurs somewhere between the 0.4 and $0.5\text{m}/\text{day}$ natural flow velocities. Similar comparisons for the first two examples are not presented because flow line breakthrough does not apply to the first example (a single production well) and the flow line did not indicate breakthrough at $1.0\text{m}/\text{day}$ for the second example (a line of five wells).

The presence of an unknown well is being studied in Figure 9. A major pumping well ($1,000\text{m}^3/\text{day}$) has been arbitrarily located downgradient of the same line

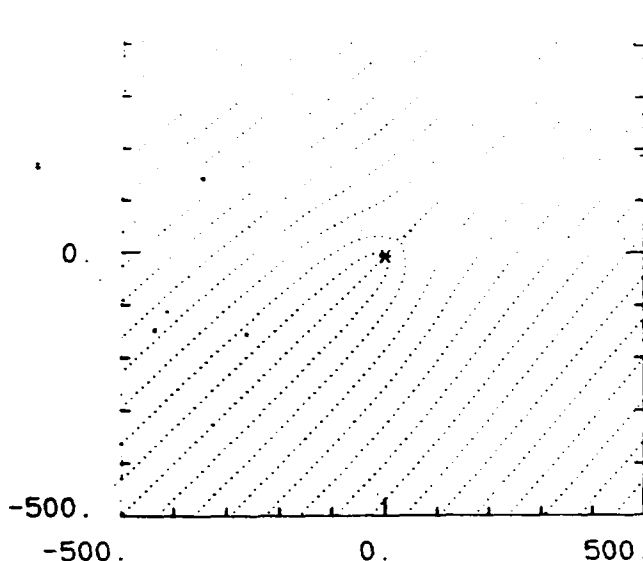


Figure 7A. Single well discharging 1,000m³/day

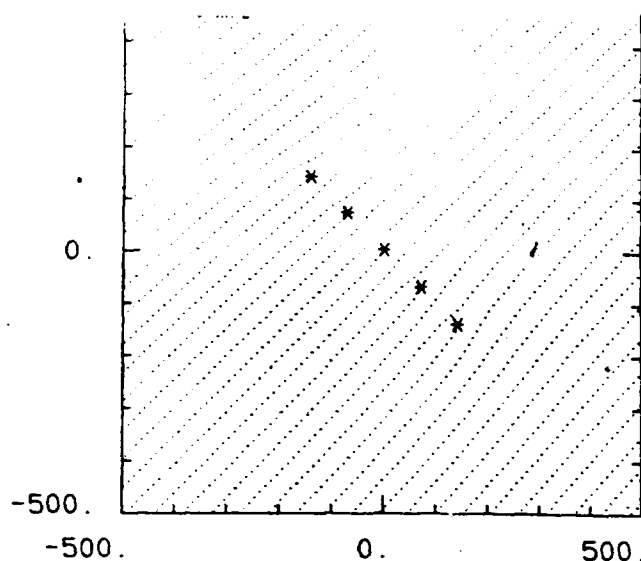


Figure 7B. Line of five wells, each discharging 200m³/day

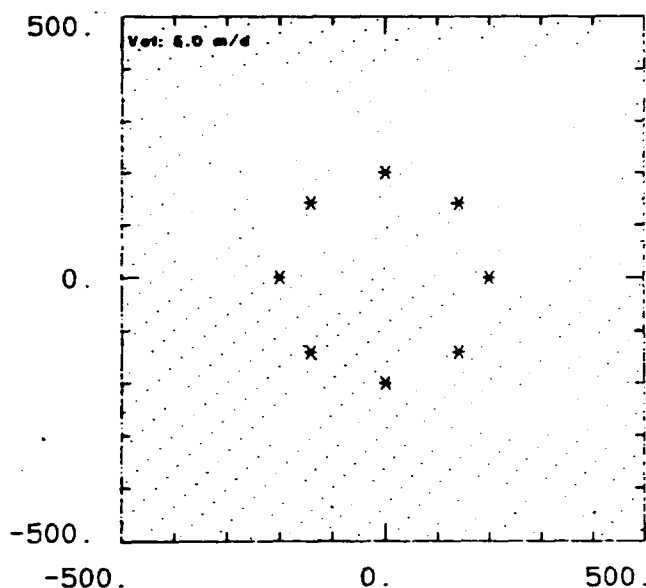


Figure 7C. Circle of eight wells, each discharging 125m³/day

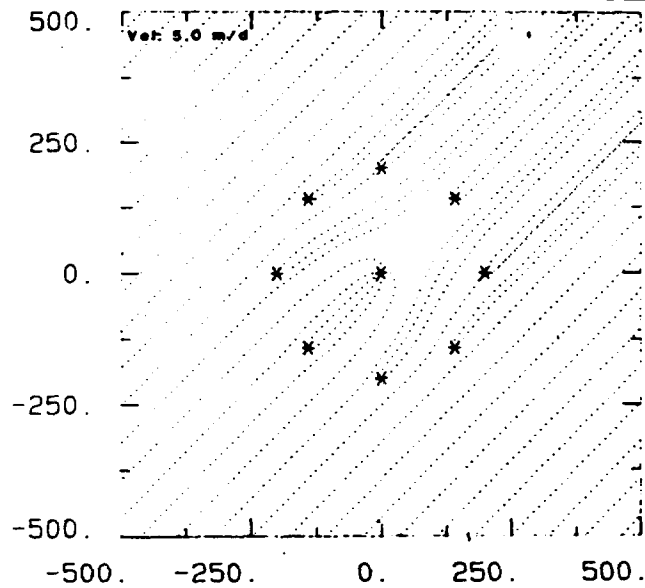


Figure 7D. Single well discharging 1,000m³/day, encircled by eight wells injecting 125m³/day each

Figure 7. Comparison of pumping arrays in an aquifer with 10m saturated thickness, 100m/day hydraulic conductivity, 0.10 porosity and 0.005 hydraulic gradient

NOTE: Scale is in meters and natural flow proceeds from lower left-hand corner to upper right-hand corner of each plot at the velocity indicated.

of five wells discussed in the second example. Naturally, under stagnant aquifer conditions, the unknown well creates a hydraulic divide by distorting the flow field, but it does not cause breakthrough of the flow line from across the line of five wells (Figure 9A). With a natural flow velocity of 0.5m/day, however, flow lines do begin to break through the line of five pumping wells (Figure 9B). Substantial failure of the pumping scheme occurs at 1.0m/day natural flow velocity (Figure 9C). Contrast the onset of breakthrough due to unknown pumpage (Figure 9B) with the same situation in the absence of the unknown pumpage (Figure 9D). The impact of the unknown well is staggering, not only because flow line breakthroughs are occurring, but the collective size of the capture zones of the five pumping wells is being substantially reduced.

Another illustration of the impact of an unknown well on the effectiveness of a pumping scheme is shown in Figure 10, which is the same example as discussed earlier (Figure 6) for a closed-loop aquifer rehabilitation system. Under stagnant aquifer conditions, the unknown well diverts flow away from two of the injection wells (Figure 10A). At 1.0m/day natural flow velocity, the unknown well diverts flow from five of the eight injection wells (Figure 10B). It also allows flow to break away from the well field entirely, as indicated by the streamline leaving the uppermost injection well and heading downgradient in Figure 10B. The regional flow lines were omitted from Figure 10 and some of the diagrams in previous figures because inclusion of those flow lines would create confusion due to the excessive number of plotted points.

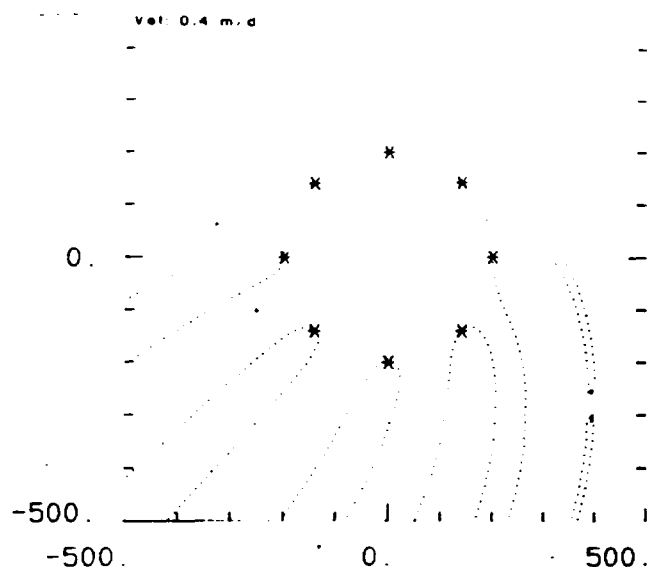


Figure 8A. Circle of eight wells, each discharging $125\text{m}^3/\text{day}$ with 0.0004 hydraulic gradient

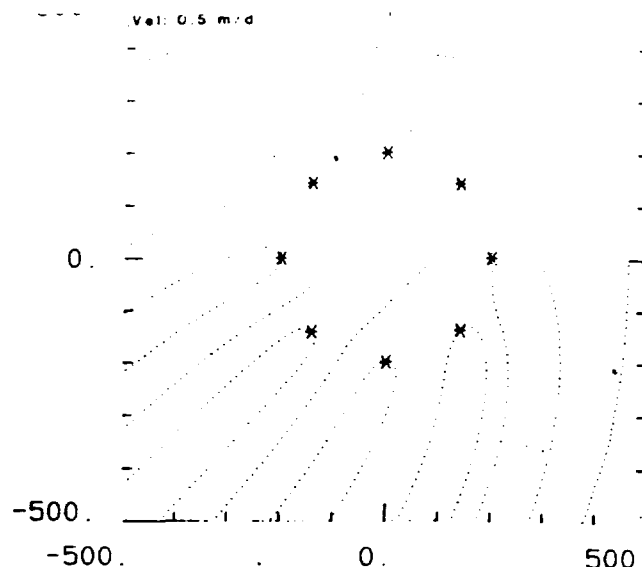


Figure 8B. Circle of eight wells, each discharging $125\text{m}^3/\text{day}$, with 0.0005 hydraulic gradient

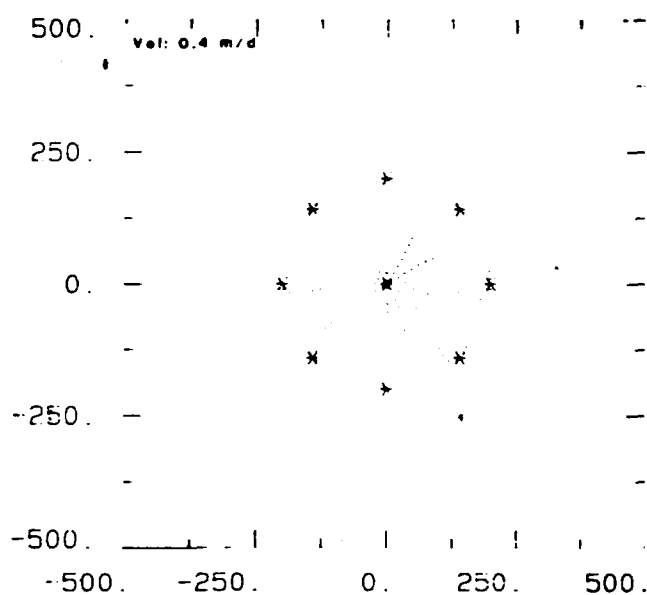


Figure 8C. Single well discharging $1,000\text{m}^3/\text{day}$, encircled by eight wells injecting $125\text{m}^3/\text{day}$ each, with 0.0004 hydraulic gradient

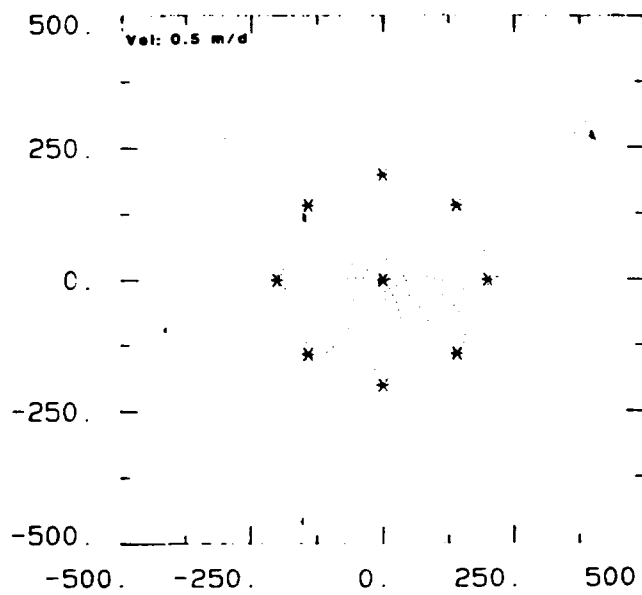


Figure 8D. Single well discharging $1,000\text{m}^3/\text{day}$, encircled by eight wells injecting $125\text{m}^3/\text{day}$ each, with 0.0005 hydraulic gradient

Figure 8. Detailed views of the onset of flow line breakthroughs for two plume control strategies in an aquifer with 10m saturated thickness, 100m/day hydraulic conductivity and 0.10 porosity

NOTE: Scale is in meters and natural flow proceeds from lower left-hand corner to upper right-hand corner of each plot at the velocity indicated.

Conclusions

Heterogeneity, anisotropy, partial penetration and so on distort drawdown patterns and associated velocity distributions. If known, such influences can be used to enhance recovery efficiencies for remedial actions. If unknown, such influences may cause recovery efficiencies to be substantially lowered. Similarly, predictions of plume migration in non-ideal aquifers under non-pumping/natural flow conditions will be strengthened by specific knowledge regarding the occurrences, extent and magnitude of the non-ideal condition(s). Such predictions may be seriously in error if non-ideal conditions are not evaluated properly.

Denial of property access, loss by vandalism and

unpredictable operation of nearby wells are also major sources of uncertainty in predicting contaminant migration and in designing remedial actions. Though commonly perceived to be less of an impact on optimizing pumping strategies than non-ideal aquifer conditions, these factors may indeed be the most uncontrollable and the most detrimental to operational success. Other factors that have major impacts are the physiochemical attenuation and biotransformation potentials of the individual contaminant; it is not yet economically feasible to conduct adequately detailed studies of these potentials on a routine site-specific basis. Finally, a factor often overlooked that greatly impacts optimization efforts is the risk of

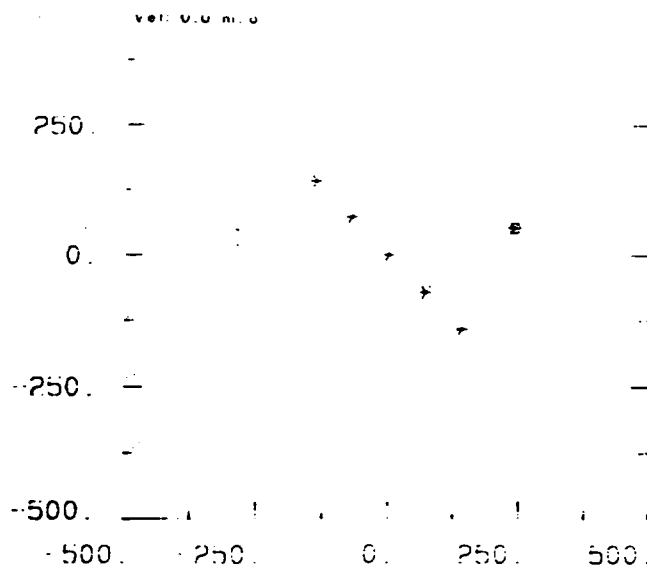


Figure 9A. Stagnant aquifer conditions

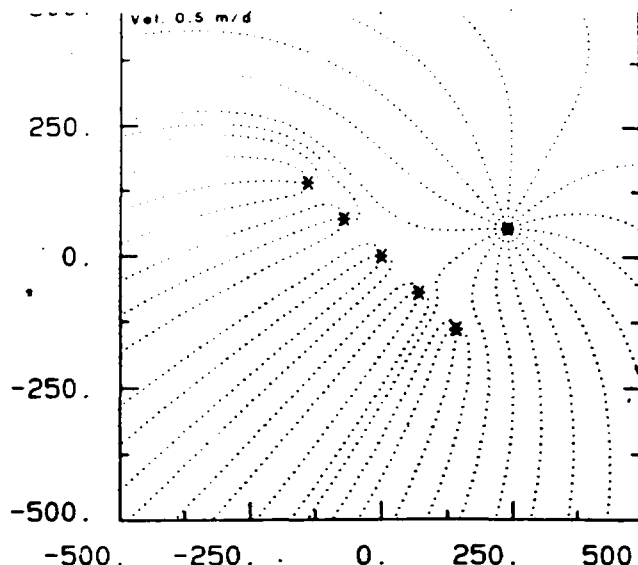


Figure 9B. Hydraulic gradient of 0.0005

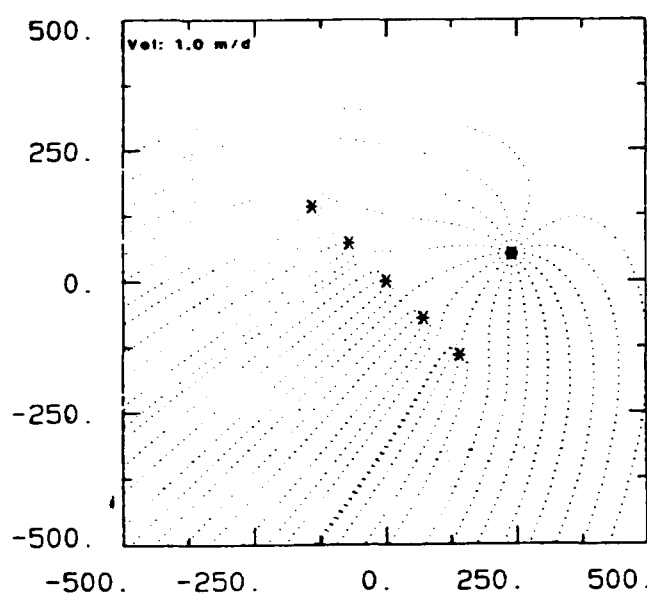


Figure 9C. Hydraulic gradient of 0.001

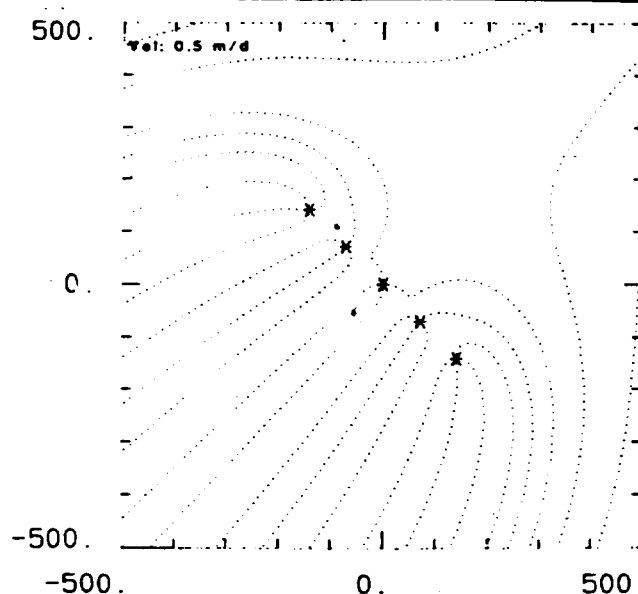


Figure 9D. Hydraulic gradient of 0.0005—without the unknown well

Figure 9. Influence of an unknown well discharging 1,000m³/day on flow line breakthroughs for a line of five wells discharging 200m³/day each from an aquifer with 10m saturated thickness, 100m/day hydraulic conductivity and 0.10 porosity

NOTE: Scale is in meters and natural flow proceeds from lower left-hand corner to upper right-hand corner of each plot at the velocity indicated.

mechanical and electrical operational failure; adequate contingency plans must provide certain minimal levels of excess/reserve capacity and redundancy of key system components.

The capture zones of wells do not equal their associated zones of pressure influence (cones of depression), except for stagnant aquifer conditions. Velocity distribution plots must be constructed to define potentials of contaminant migration. In particular, plotting the streamlines for various scenarios involving pumping and/or injection wells subject to a specific natural flow velocity can greatly assist the ground water professional in selection of an optimal pumping strategy.

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Disclaimer

Although this article was produced by an employee of the United States Environmental Protection Agency, it has not been subjected to Agency review and therefore does not necessarily reflect the views of the Agency; no official endorsement should be inferred.

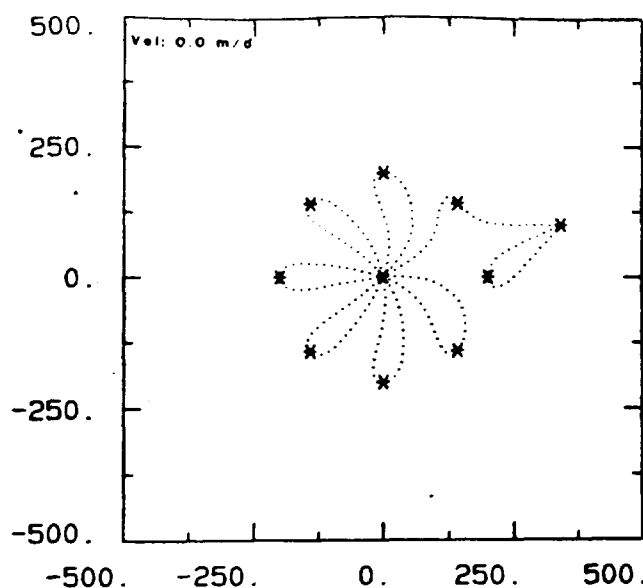


Figure 10A. Stagnant aquifer conditions

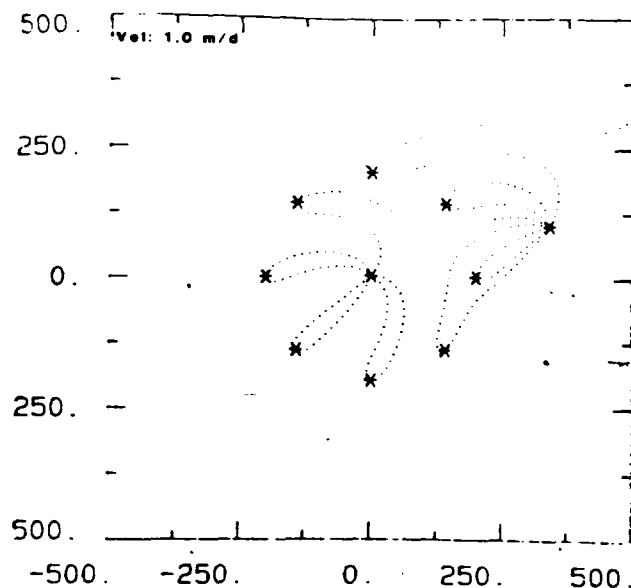


Figure 10B. Hydraulic gradient of 0.001

Figure 10. Influence of an unknown well discharging $1,000\text{m}^3/\text{day}$ on flowline breakthroughs for a single well discharging $1,000\text{m}^3/\text{day}$ that is encircled by eight wells injecting $125\text{m}^3/\text{day}$ into an aquifer with 10m saturated thickness, 100m/day hydraulic conductivity and 0.10 porosity.

NOTE: Scale is in meters and natural flow proceeds from lower left-hand corner to upper right-hand corner of each plot at the velocity indicated.

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Biographical Sketch

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Effectiveness of Various Aquifer Restoration Schemes Under Variable Hydrogeologic Conditions

by Richard L. Satkin^a and Philip B. Bedient^b

ABSTRACT

The USGS MOC Model is a useful tool for evaluating different well patterns in an aquifer restoration scheme under variable hydrogeologic conditions. The best well pattern for a ground-water cleanup is highly site-specific and depends upon the objectives and constraints for each problem. In this study, seven different well patterns were investigated to determine the one(s) most efficient in achieving a range of desired levels of contaminant reduction. The well patterns were evaluated on the basis of cleanup time, volume of water circulated, and volume of water requiring treatment. Eight generic hydrogeologic conditions were modeled using different combinations of drawdown, hydraulic gradient, and dispersivity. The key hydrogeologic variables which control the rate of cleanup are well locations, pumping rates, transmissivity, dispersivity, and hydraulic gradient. For a given set of well locations, by varying transmissivity and maintaining drawdown, dispersivity, and hydraulic gradient constant, the cleanup time was found to be inversely related to the pumping rate.

INTRODUCTION

The question of whether a polluted aquifer can be restored and how best to proceed is dependent upon the hydrogeologic and geochemical properties of the aquifer and on the chemical and physical properties of the contaminant (Konikow and Thompson, 1984). Common restoration options typically considered include the following: (1) the no-action alternative which relies on natural attenuation and dilution after source removal; (2) ground-water pumping; (3) containment, either

physical and/or hydraulic; (4) excavation and removal of the contaminated part of the aquifer; and (5) in situ biological or chemical treatment.

Ground-water pumping is probably the most common method employed for aquifer restoration. Reinjection of treated water eliminates the potentially high cost of disposal and at the same time accelerates the removal of contaminants by increasing the hydraulic gradient. In addition to providing hydrodynamic control to contain the contaminant plume to a specified area, the pumping and injection wells may play a more active role by delivering and removing chemical substances for an in situ treatment process or removing the contaminant for surface treatment and reinjection. The general objective in a pumping and injection scheme is to create a ground-water divide or a capture zone which completely encompasses the contaminant plume. The key variables which control the efficiency of the withdrawal scheme and the size and shape of the capture zone depend upon the contaminant chemistry, well locations, pumping rates, and the aquifer properties such as transmissivity, dispersivity, and hydraulic gradient.

This study simulates the removal of a non-reactive contaminant plume using different well configurations for several generic hydrogeologic conditions. Seven different well patterns were studied to determine which well pattern(s) is the most efficient in achieving a range of desired levels of contaminant reduction. The cleanup objective was to reduce the maximum contaminant concentration in the plume by a range of levels, up to 99.995%, as quickly as possible, and at the same time not allow any contaminant to migrate further than 50 feet from the initial downgradient edge of the plume. The well patterns were evaluated on the basis of cleanup time, volume of water circulated,

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Table 1. Different Generic Hydrogeologic Conditions Modeled

GENERIC HYDROGEOLOGIC CONDITIONS			
Condition	Maximum Drawdown	Hydraulic Gradient	Longitudinal Dispersivity
A	High s	Low i	Low a
B	Low s	Low i	Low a
C	Low s	Low i	High a
D	High s	Low i	High a
E	Low s	High i	Low a
F	High s	High i	Low a
G	High s	High i	High a
H	Low s	High i	High a

High s = ≤ 10 ft
 Low s = ≤ 5 ft
 High i = .008
 Low i = .0008
 High a = 30 ft
 Low a = 10 ft

and volume of water requiring treatment. Eight generic hydrogeologic conditions shown in Table 1 were modeled using different combinations of drawdown, hydraulic gradient, and dispersivity.

PREVIOUS WORK

Analytical and numerical modeling are both commonly used to screen and evaluate different remedial options for aquifer restoration. Numerical models are more flexible than analytical solutions because complex boundary conditions with various combinations of pumping and injection wells can be approximated easily by arrangement of grid cells. Numerical techniques commonly employed for simulating ground-water transport include finite-difference and finite-element methods and the method of characteristics (MOC). The method of characteristics (MOC) is most useful when solute transport is dominated by advective transport (Konikow and Bredehoeft, 1978), as in the case of most aquifer restoration schemes involving pumping and injection. The method of characteristics (MOC) also minimizes numerical dispersion, a problem plaguing many numerical methods.

Many investigators have used numerical ground-water models as a tool in the design of aquifer restoration strategies because they provide a rapid means of predicting or assessing the effects of different remedial alternatives. Andersen *et al.* (1984) used a finite-difference ground-water model as an aid in selecting an appropriate remedial action at the Lipari Landfill in New Jersey. Using a finite-element model, Tsai and Zielen (1985) compared six pumping schemes for withdrawal of ground water contaminated with explosive wastes at an

ammunitions plant in Nebraska. They found that extraction wells located along the plume axis are more effective than pumping schemes with the same number of wells located in groups over the plume area. Althoff *et al.* (1981) used a ground-water flow model to test a variety of well configurations, well locations, and pumping rates for hydraulic capture of a 1000-ft-long 1,1,1-trichloroethane plume. Freeberg *et al.* (1987) delineated a trichloroethylene plume and used the USGS MOC Model to evaluate different withdrawal schemes at an industrial waste site.

To select the best well configuration for a particular withdrawal scheme requires the ability to predict changes in flow and chemical concentration in the aquifer for each possible management alternative (Konikow and Thompson, 1984). The best pumping arrangement at a field site is developed generally by a tedious trial and error process (Glover, 1982). The trial and error approach suffers because it is inefficient; however, the heuristic knowledge gained by the user is invaluable and allows the modeler to steadily improve on future trials. Alternatively, several investigators (Gorelick, 1983, 1984, 1986; Molz and Bell, 1977; and Shafer, 1984) have demonstrated how linear or nonlinear programming (optimization techniques) can be combined with a ground-water transport model to efficiently arrive at an optimal design strategy.

NUMERICAL MODEL

The USGS MOC Solute Transport Model (Konikow and Bredehoeft, 1978) is one of the most widely used 2-D ground-water transport models. The model computes changes in concentration over time caused by the processes of advective transport, hydrodynamic dispersion, mixing (or dilution) from fluid sources, first-order decay, and equilibrium sorption-desorption. The model is well-suited for evaluating alternative pumping schemes because it is well-documented, has simple input/output formats that can be modified easily, allows any number and arbitrary placement of injection and pumping wells, and has time-variable pumping periods.

To simulate solute transport, the computer program solves two partial differential equations simultaneously using numerical methods. It uses an iterative alternating direction implicit (ADI) procedure to solve a finite-difference approximation to the ground-water flow equation, and it uses the method of characteristics (MOC) to solve the

PARAMETER SELECTION

In order for the results of this project to have widespread applicability, values for the ground-water model parameters which describe the pollutant transport and withdrawal scheme need to be representative of actual field sites. The key variables are hydraulic conductivity, aquifer thickness, hydraulic gradient, dispersivity, drawdown, concentration, plume shape and size, and well pattern.

Hydraulic conductivity, K , is perhaps the most difficult parameter to assign at a hazardous waste site without a very detailed sampling program. In ground-water modeling, hydraulic conductivity is normally the most sensitive parameter. One of the reasons is that K can vary over a large range for a typical site (several orders of magnitude). Hydraulic conductivity is embedded in the transmissivity term as required input for the USGS MOC Model. The ratio of T_{xx}/T_{yy} allows specification of anisotropy. However, for the sake of applicability and ease of use, transmissivity is considered homogeneous and isotropic for this analysis. Due to the wide range of values possible for K , it is impossible to assign a generic value. The hydraulic conductivity values initially selected for the study, 10^{-5} , 10^{-4} , 10^{-3} , 10^{-2} , and 10^{-1} ft/sec (1 ft/sec = 30.48 cm/sec) range from a typical silty sand aquifer to a gravel aquifer.

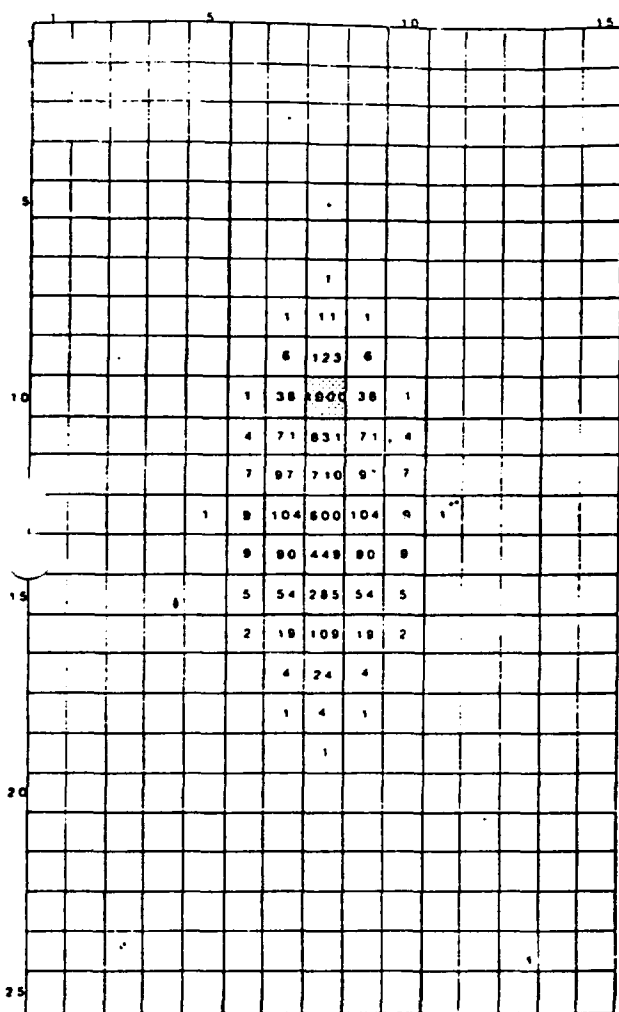
The aquifer thickness, B , is a highly site-specific parameter and is dependent upon the local stratigraphy and geologic structure. In contaminant transport, the aquifer thickness influences the opportunity for vertical dispersive mixing as the contaminant plume moves downgradient. During aquifer restoration, the maximum amount that a well can pump is constrained by the thickness of the aquifer. In this study, the aquifer thickness was set to a constant value of 10 ft, a fairly typical value. The transmissivity term may be used to adjust for aquifer thickness or hydraulic conductivity.

The hydraulic gradient is roughly equivalent in magnitude and direction to the topographic slope at a regional scale. At the scale of a site investigation, however, the hydraulic gradient may differ substantially due to man-made influences, including pumping wells and areas of enhanced recharge (landfills) (Guswa *et al.*, 1984). Cleanup simulations were made with both a low (.0008) and a high (.008) background hydraulic gradient. The regional flow regime was incorporated into the model as two rows of parallel constant head boundaries at both ends of the 15 x 25 finite-difference grid used in the analysis.

The dispersion coefficient, D , is an important parameter because it controls the degree of spreading and dilution of a pollutant plume. The dispersion process results primarily from mechanical mixing, attributed to both hydrodynamic dispersion, resulting from velocity variations in each pore channel, and macrodispersion, resulting from small-scale velocity variations due to variations in hydraulic conductivity (Freeze and Cherry, 1979). Mechanical mixing is the dominant process at the relatively high velocities typically encountered in aquifer restoration schemes (Gillham, 1982). The molecular diffusion component becomes significant only when ground-water velocities are very slow. In the USGS MOC Model, the molecular diffusion term is neglected.

Several investigators (Anderson, 1979, 1984; Pickens and Grisak, 1981) have noted that dispersivity varies with the scale of the analysis. Until very recently, it was not clear whether the dispersivity increases indefinitely with scale or reaches an asymptotic value as predicted by recent stochastic theories (Gelhar *et al.*, 1985). Data obtained from a contaminant plume over two miles in length at the Otis Air Force Base at Cape Cod, Massachusetts, indicate that the longitudinal dispersivity at this site asymptotically approaches a value of 1 m. The transverse dispersivity is 2% (0.02 m) of the longitudinal dispersivity (LeBlanc and Hess, 1987). At the Borden landfill in Canada, the asymptotic longitudinal dispersivity after 1038 days of travel approaches 0.5 m; however, asymptotic conditions were apparently not reached. The transverse dispersivity is 10% (0.05 m) of the longitudinal dispersivity and shows no increase in magnitude, analogous to the behavior of the longitudinal dispersivity (Freyberg, 1986).

Due to the difficulty in obtaining a detailed measure of the spatial variability of the aquifer and the long travel times associated with a contaminant plume, it is very difficult to obtain a good field measure of dispersivity. Gelhar *et al.* (1985) provide a critique of 55 reported field-scale dispersivity tests. The most extensive study to date is a natural gradient field tracer experiment which used multilevel sampling at the Borden landfill site in Canada. Transverse and vertical dispersivity have been studied to a lesser degree than longitudinal dispersivity. In the current study both a high (30 ft) and a low (10 ft) longitudinal dispersivity were used in the simulations. In the USGS MOC Model, dispersivity is constant both temporally and spatially. A transverse dispersivity of 30% of the longitudinal dispersivity was used in the model and



1. Contaminant plume used in this study.

may be slightly high based upon recent field studies. The values chosen for this study are within the range of field-reported values, and are used primarily for design purposes.

In designing an aquifer cleanup operation, the selection of the number of pumping wells, discharge rates, and well locations is typically constrained by the maximum allowable drawdown, which is governed by the saturated thickness. As many contaminated aquifers are located at shallow depths, the maximum allowable drawdown at the well should reflect these situations. In the model simulations, two sets of maximum allowable drawdown were used, a large drawdown (≤ 10 ft) and a small drawdown (≤ 5 ft), both of which are relatively large compared to aquifer thickness. However, since $T = KB$ in the model, the cleanup results should be applicable over the range of parameter values selected.

The simulated contaminant plume used in this study (Figure 1) was created using a single injection well. Table 2 summarizes the aquifer charac-

teristics and source loading parameters used in creating the plume with the USGS MOC Model. The objective in creating this plume was not to match a known plume, but rather to create a plume having a typical tear-drop shape with a maximum dimensionless concentration of 1000 units. The shape of the actual plume is irrelevant since the analysis provides a general indication of the relative effectiveness of various withdrawal schemes under isotropic, homogeneous conditions. The results of the various simulations should be used cautiously at any actual waste sites where heterogeneous conditions exist. Results are presented with dimensionless concentration for widespread application.

WELL PATTERNS

There are many possible arrays or patterns in which to place ground-water wells. The seven different well patterns, shown in Figure 2, were evaluated for their effectiveness in remedial cleanup. The doublet, as in any production/injection scheme, improves the flushing rate over that of a single production well because of the increased hydraulic gradient towards the production well. However, the doublet also leads to larger volumes of water requiring treatment with smaller concentrations. Under high gradients, the three-spot pattern may be superior to that of a doublet because of the hydraulic barrier created by the downgradient injection well. The downgradient recharge well could also provide a backup to the production well if the production well should fail. The five-spot well pattern is commonly used in the

Table 2. Source Loading and Aquifer Characteristics for Creating the Initial Plume

Parameter	Value
Well location	col = 8, row = 10
Injection rate	0.25E-5 ft ³ /sec (1.6 gpd)
Concentration	15000 units
Pumping period	30 yr
Hydraulic gradient, i	0.0008
Hydraulic conductivity, K	0.0001 ft/sec
Thickness, b	10 ft
Longitudinal dispersivity, α_L	10 ft
Transverse dispersivity, α_T	3 ft
Effective porosity, n	30%

* Concentration can be any set of units.

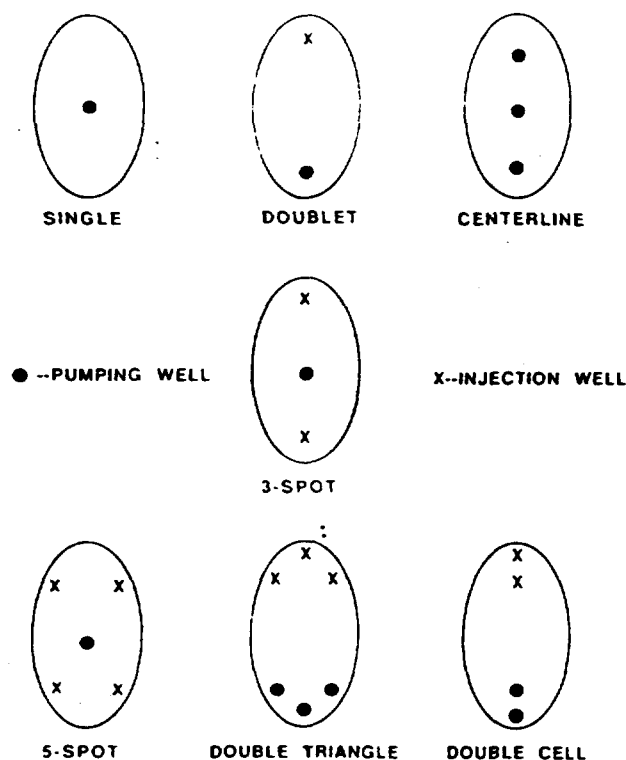


Fig. 2. Well patterns used in this study.

petroleum industry particularly in secondary recovery by water flooding.

The double-cell hydraulic containment system (Wilson, 1984) consists of an inner cell and an outer recirculation cell using four wells along a line bisecting the plume. The inner cell can be designed large enough to just capture the plume. The outer cell serves to create a steep hydraulic gradient through the plume by circulating a much larger volume of water than the inner cell. The presence of the outer cell reduces the time required to capture the plume and the amount of water requiring treatment. The double-triangle pattern represents a modification of the double-cell hydraulic containment system.

In both the single and centerline well patterns, there is no injection. In the other well patterns, the injection rate was set equal to the pumping rate so that the total volume of water withdrawn from the aquifer was reinjected back into the aquifer. In these analyses, the volume of water injected was always equally distributed among each injection well.

NUMERICAL SIMULATION PROCEDURE

Hydrogeologic condition A (Table 1) was investigated first. Condition A has a drawdown of ≤ 10 ft (high value), a hydraulic gradient of 0.0008 (low value), and a dispersivity of 10 ft (low value).

A hydraulic conductivity, K of 10^{-4} ft/sec was used in this first set of runs. The single well was the first pattern investigated. The pumping rate was estimated by using the Thiem equation. The approximate length of time required for the simulation was determined using the seepage velocity. In order to narrow down the possible locations for the well, the capture zone and stagnation point were estimated using analytical equations. Once a well location and pumping rate were selected, a simulation with a very short pumping period (.001 yr) was made in order to observe the steady-state draw-down. The pumping rate was then adjusted accordingly to meet the drawdown criteria, and a final computer run was made.

Based upon nine observation wells or blocks in the model, the time required for the entire aquifer to attain a concentration at or below 100.0, 10.0, 1.0, 0.1, and $< .05$ units was noted. For each well pattern investigated, several additional computer runs were made each time varying the well locations. The computer run selected as the final one was able to reduce the maximum concentration to $< .05$ units in the shortest time. This concentration represents a 99.995% concentration reduction from the source block (C_{source}).

RESULTS

Well Location

Cleanup time is a function of the velocity field which is governed by both the locations of wells with respect to the contaminant plume and the regional flow field. The resultant contaminant velocity is the sum of the velocity produced by the pumping well plus the natural flow in the aquifer. Under a low natural flow, it would not be practical to site a single extraction well at the downgradient edge of a plume, as it would take a long time for the contaminant to reach the well. Under a high natural flow, however, it might be advantageous to place the extraction well near the downgradient edge of a plume. If the well is placed near the up-gradient side of the plume, contaminant flow toward the well would be countered by the high natural flow away from the well and contaminant may become trapped in a zone of low flow, or a stagnation area.

Significant differences in cleanup time were observed using different well locations for a given well pattern. Table 3 illustrates the impact that a well location has on cleanup time for a single extraction well with a low hydraulic gradient. A 50-foot difference in location added up to a year in the overall cleanup time. In this case, run 1a

was selected as final because it achieved a concentration of $< .05$ units in the shortest time.

Water Requirements for Cleanup

By selecting the run with the shortest cleanup time, the volume of water requiring treatment is also minimized, although this may not be the absolute minimum volume of water necessary to achieve the cleanup. In order to find the absolute minimum amount of water requiring treatment, it would be necessary to create a perfect capture zone encompassing only the contaminant plume. By creating such an ideal capture zone, the cleanup time is increased significantly because of the lower pumping rates required. In this study, the withdrawal schemes focused on attaining a rapid cleanup through a prescribed maximum level of drawdown, rather than the creation of a perfect capture zone.

Pumping rates can be computed that would be just large enough to capture a plume for a single and doublet well configuration. Figure 3 shows two capture zones computed for a single well at two different flow rates. Two important points are illustrated in this Figure 3. First, to completely remove the contaminant plume, the extraction well will have to accept some uncontaminated water from upgradient. Using the outer capture zone in Figure 3, there are approximately 26 cells containing zero contaminant that would be accepted into the well before the last of the contaminant is

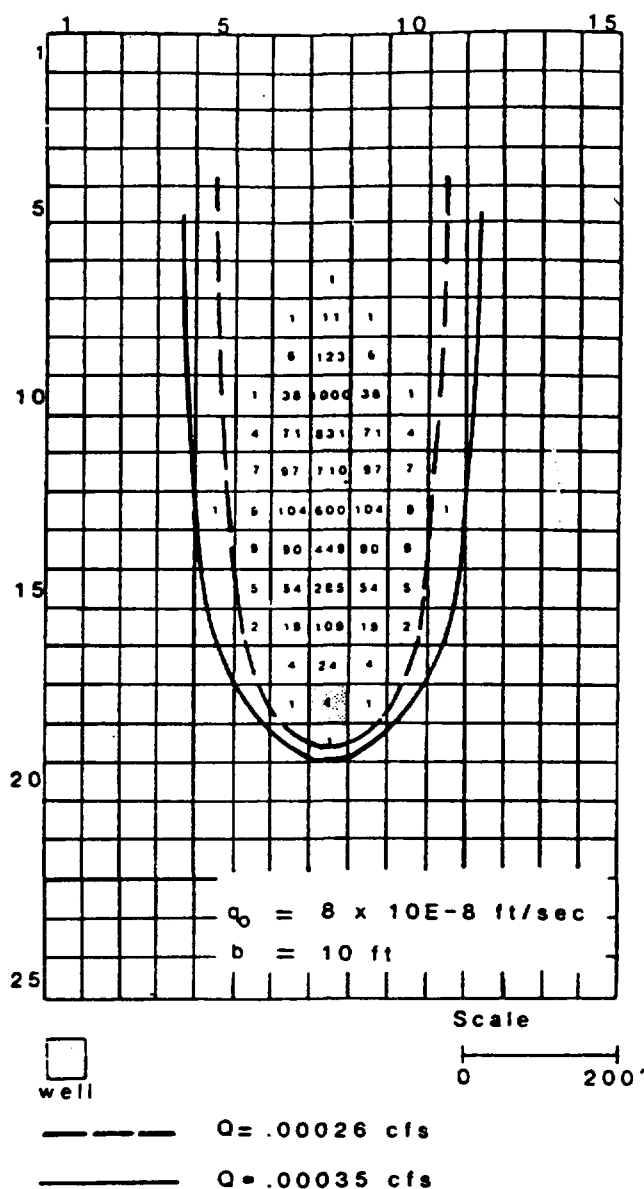


Fig. 3. Single-well capture zones for different pumping rates.

withdrawn. This results in a minimum of 1.5 pore volumes being treated. Second, the use of a finer grid spacing may help because the ground-water divide bisects several contaminated grid cells.

Low Gradient Cases

Under hydrogeologic condition A (Table 1), all of the cleanup schemes were simulated and results are given in Figure 4. In terms of final cleanup time (time required for the entire aquifer to achieve a relative concentration of $< .00005$), the pattern with the greatest number of wells, double-triangle, takes the least time, but the difference (.07 yr) between the double-triangle and double-cell is insignificant (Figure 4). Overall, the double-cell pattern is most effective in terms of cleanup time. The single well takes the most time

Table 3. Effect of Well Location on Cleanup Time

WELL LOCATION		CLEANUP TIME	
col, row	C_{max}/C_{source}	time (yr)	run #
8 12	1.0	0.0	1
	0.1	0.54	
	0.01	1.45	
	0.001	2.52	
	0.0001	3.36	
	< 0.00005	3.96	
8 13	1.0	0.0	1a
	0.1	0.60	
	0.01	1.32	
	0.001	2.04	
	0.0001	2.78	
	< 0.00005	3.19	
8 14	1.0	0.0	1b
	0.1	1.10	
	0.01	1.88	
	0.001	2.73	
	0.0001	3.53	
	< 0.00005	> 4.00	

$Q_w = 0.012$ cfs
 $s = 10$ ft
 $i = 0.0008$
 Long. dispersivity, $\alpha_L = 10$ ft
 $K = 0.0001$ ft/sec
 $b = 10$ ft

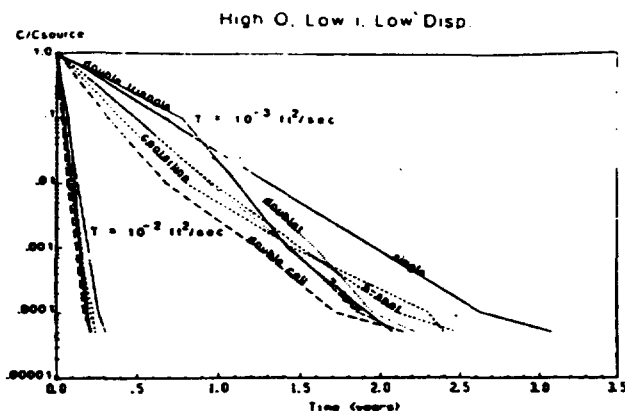


Fig. 4. Comparison of relative concentrations vs. cleanup time for various well patterns—condition A.

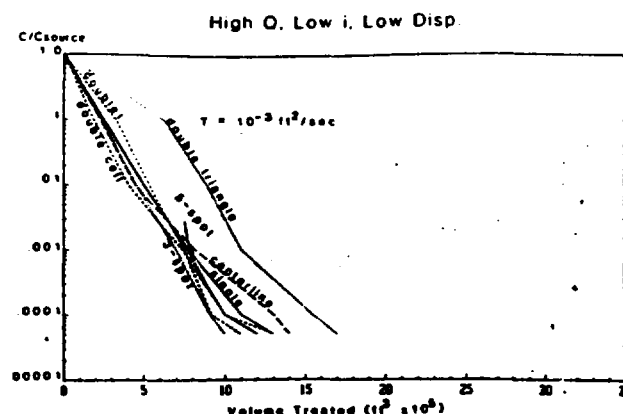


Fig. 5. Comparison of relative concentrations vs. volume of water treated for various well patterns—condition A.

to attain the final cleanup criteria. Results for the five-spot well pattern were discouraging, but the poor performance is attributed to the limited hydraulic benefits of only four injection wells. In the petroleum industry, multiple five-spot patterns are employed which result in an equal number of production and injection wells.

Except for the five-spot pattern, the withdrawal schemes having both pumping and injection wells attain final cleanup more quickly than the single and centerline well patterns which utilize only pumping wells. This results from the steeper hydraulic gradient created by the injection wells. The benefits of a decreased cleanup time using injection wells are countered by an increase in the volume of water circulated. Overall, there is not a very significant difference in final cleanup time among the different schemes with injection wells at a transmissivity of 10^{-3} ft²/sec.

Determining the most effective well pattern for a ground-water cleanup is highly site-specific, and is greatly affected by spatial heterogeneity. Such factors as contaminant concentration, treatment process, size of treatment facility, maintenance, pumping costs, sampling, and monitoring, to name a few, need to be evaluated. Based upon the results obtained in this study, the three-spot, doublet, and double-cell appear to be the most promising well patterns for a high drawdown, low hydraulic gradient, and low aquifer dispersivity. These well patterns minimize the total volume of water circulated, volume of water treated (Figure 5), and cleanup time. The double-cell is the most efficient well pattern for achieving up to a 99.9% reduction in contaminant concentration. Beyond this level, the volume of water circulated using the double-cell increases significantly.

Under hydrogeologic condition B (Table 1),

the single, doublet, and double-triangle patterns were simulated using the same well locations that were used in condition A. The only difference between condition A and condition B is the smaller drawdown under condition B. In order to achieve a maximum drawdown of ≤ 5 ft, the pumping rates used in condition A were decreased by 50%.

Cleanup times increased to almost exactly twice that of the cleanup times in condition A. Based upon this finding, Figure 4, showing relative concentration versus cleanup time for condition A, is applicable to condition B if the time (abscissa) is multiplied by a factor of two. Figure 5, showing relative concentration versus volume of water treated, is applicable as is because the increase in cleanup time is exactly canceled out by the decrease in pumping rate so that the volume of water is identical.

The double-triangle pattern was tested under hydrogeologic condition C. Final cleanup time increased fourfold compared to condition A due to the lower drawdown used with the higher aquifer dispersivity for condition C. With the same well locations as condition A, the doublet and double-triangle patterns were simulated under hydrogeologic condition D. As a result of the large amount of dispersive mixing during early times in condition D ($\alpha = 30$ ft), less time was required to achieve a 90% reduction in contaminant concentration than with the lower dispersivity ($\alpha = 10$ ft) used in condition A. However, increasingly longer times than required for condition A were needed to achieve any further reductions in concentration as shown in Table 4. Under hydrogeologic condition D, attaining a 99.995% reduction in concentration takes about twice as long as condition A.

A detailed analysis of the mass rate of removal versus well patterns was completed and

yielded results similar to the concentration cleanup curves. This analysis did not provide any further insight into efficiency of the well patterns and was not continued for the high gradient cases.

High Gradient Cases

The effect of a high hydraulic gradient (.008) is illustrated in Table 5, which compares final cleanup time and the number of pore volumes treated for condition E and condition B (low s , low i , low α). With a higher hydraulic gradient, more time and additional pore volumes are required to achieve final cleanup than with the lower hydraulic gradient. The double-triangle well pattern is an exception. The hydraulic gradient has no effect upon the double-triangle pattern because the flow regime is so strongly dominated by the well field. The doublet which performs very well under low hydraulic gradient conditions is ineffective under a high hydraulic gradient.

The three-spot is the preferred well pattern under hydrogeologic condition E. Constrained by the maximum allowable drawdown, containing the contaminant plume under this high hydraulic gradient is difficult. The downgradient injection well in the three-spot, however, provides for a distinct advantage over the other well patterns. The three-spot pattern requires the least volume of water for treatment (Figure 7) and is second to the double-triangle in cleanup time (Figure 6). Under hydrogeologic condition F, the centerline, three-spot and doublet well patterns were simulated using the well locations optimized under condition E. Pumping rates were increased 100% in order to attain twice the drawdown of condition E. With the higher pumping rates, cleanup times decreased by approximately 60%. It is interesting to note that with a low hydraulic gradient, doubling the pumping rates decreased cleanup times by 50%. This result suggests that the hydrodynamic dispersion mechanism of contaminant transport is significant at higher velocities. Figure 6 shows relative concentration versus cleanup time for condition E and is applicable under condition F if the time (abscissa) is multiplied by a factor of 0.6. Figure 7, showing relative concentration versus volume of water pumped, is applicable to hydrogeologic condition F if the volume of water (abscissa) is multiplied by 1.2.

The single, doublet, and three-spot well patterns were simulated under hydrogeologic condition G. Because of the higher dispersivity, a change in the well locations from those used in condition E for both the single and doublet patterns

Table 4. Effect of Dispersivity on Cleanup Time

EFFECT OF DISPERSIVITY ON CLEANUP TIME						
Hydrogeologic Condition	Pattern	Cleanup time (yr) for various C/C_{source}				
		.1	.01	.001	.0001	<.00005
A (Low Disp.)	Doublet	0.69	1.14	1.59	1.95	2.22
D (High Disp.)	Doublet	0.63	1.36	2.22	3.50	4.38
A (Low Disp.)	Double Triangle	0.78	1.11	1.42	1.92	2.08
D (High Disp.)	Double Triangle	0.46	0.95	1.71	2.87	4.42

Hydrogeologic Condition A - High s , Low i , Low α
Hydrogeologic Condition D - High s , Low i , High α

Table 5. Effect of Hydraulic Gradient on Cleanup Schemes

EFFECT OF HYDRAULIC GRADIENT ON FINAL CLEANUP		
Cleanup time in years (# of pore volumes)		
Pattern	Hydrogeologic Condition B Low gradient time (P.V.)	Hydrogeologic Condition E High gradient time (P.V.)
single	6.16 (3.2)	6.63 (3.6)
centerline	4.80 (3.6)	5.18 (3.8)
doublet	4.44 (2.7)	5.75 (3.6)
3-spot	4.28 (2.7)	4.75 (3.1)
5-spot	4.96 (3.4)	5.54 (4.1)
double-cell	4.30 (3.4)	4.93 (3.7)
double triangle	4.16 (4.4)	4.15 (4.3)

P.V. = Number of Pore Volumes Requiring Treatment
Hydrogeologic Condition B - Low s , Low i , Low α
Hydrogeologic Condition E - Low s , High i , Low α

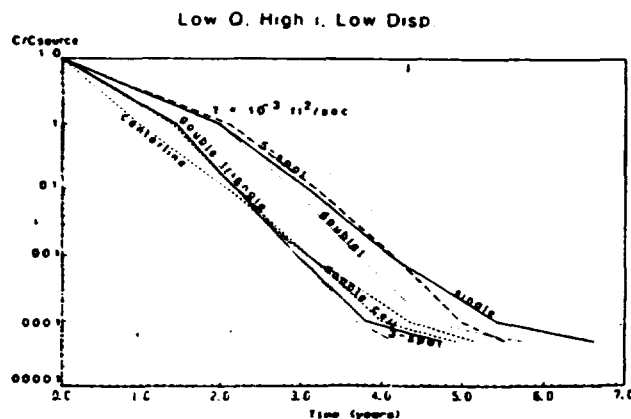


Fig. 6. Comparison of relative concentrations vs. cleanup time for various well patterns—condition B.

was necessary to contain the plume. To achieve 90% reductions in contaminant concentrations with both the single well and the doublet took approximately 40% of the times required under condition E. To achieve 99.995% reductions (final cleanup) took 90% of the times in condition E. The well locations for the three-spot were the same as those used in condition E, and achieving 99.99% and 99.995% reductions required the same amount of time as the same pattern in condition E, which is still less than the time required for either the single or doublet patterns.

All the well patterns, except for the double-cell and five-spot, were simulated using various well locations under hydrogeologic condition H. None of the withdrawal schemes were successful in containing the pollutant plume. With each well pattern, high concentrations of contaminant were observed in observation block (8,20) located 50 feet from the downgradient edge of the initial plume.

Linearity Effects

For a given withdrawal scheme, by varying transmissivity and maintaining one of the sets of hydrogeologic conditions (Table 1) as constant, the cleanup time was found to be inversely related to the pumping rate. For example, to achieve a dimensionless concentration of < 100.0 in an aquifer for a given hydrogeologic condition (Base Run) takes one year. Maintaining the same cone of depression, hydraulic gradient, and aquifer dispersivity as the Base Run and decreasing the transmissivity tenfold, the required pumping rate will be decreased tenfold according to the Thiem equation. It was observed that the cleanup time increases exactly tenfold from one year to ten years. Also, the areal distribution of the contaminant plume after ten years is exactly identical to

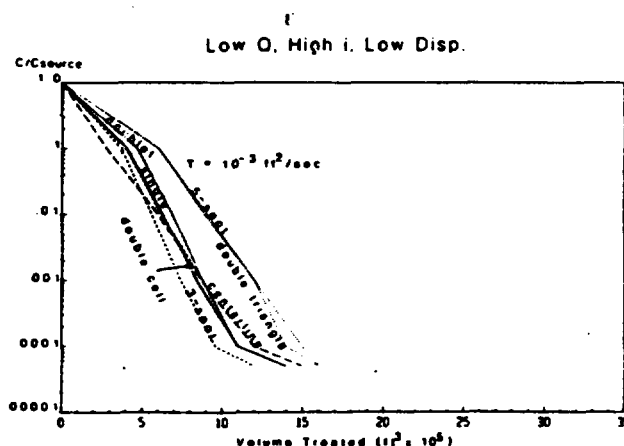
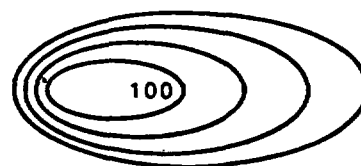
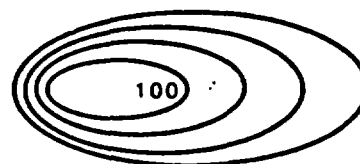


Fig. 7. Comparison of relative concentrations vs. volume of water treated for various well patterns—condition B.



TIME : 1 YEAR (Base Run)

Transmissivity: $10^{-3} \text{ ft}^2/\text{sec}$
Pumping rate : 1 cfs
Drawdown: 10 feet
Hydraulic Gradient : .001
Dispersivity : 10 feet



Time : 10 yr.

Transmissivity : $10^{-4} \text{ ft}^2/\text{sec}$
Pumping rate : 0.1 cfs
Drawdown : 10 feet
Hydraulic Gradient : 0.001
Dispersivity : 10 feet

Fig. 8. Effect of linearity on a plume cleanup.

the contaminant plume with the higher transmissivity at one year (Base Run). Dispersion has minimal effects. Figure 8 illustrates the linearity effect on a plume cleanup. This finding can be summarized by the following observation: ~~Cleanup time is inversely related to the pumping rate. The Q/T ratio or cone of depression is kept constant.~~ This finding has been verified by the Wilson and Miller (1978) 2-D analytical solution of the advection-dispersion equation.

In the absence of geochemical reactions, variations in concentration over time are the result of the processes of advection and dispersion. By varying transmissivities, the advection term changes; however, the flow field remains unchanged. The solute particles are advected along the same identical flow paths but are displaced in time corresponding to the change in transmissivity. Transport due to dispersion is affected in a similar way. In Figure 8, the amount of dispersion after one year is reduced from that of the Base Run, corresponding to the tenfold decrease in velocity. After ten years, the amount of dispersion in the lower transmissivity run is equal to that of the Base Run.

Figure 9 illustrates an application of the linearity to a three-spot withdrawal scheme. Each concentration versus cleanup time curve corresponds to an aquifer having a transmissivity

differing by a factor of ten. To maintain the same one of depression in each aquifer, the pumping rates differ by a factor of ten. The time required to attain the same desired level of cleanup in each aquifer is displaced exactly by a factor of ten and is inversely proportional to the pumping rate.

As a result of the linearity effect, a single value for transmissivity (10^{-3} ft²/sec) was used in the simulations instead of making a computer run for each cleanup scheme for each value of transmissivity. Results for a withdrawal scheme under a given set of hydrogeologic conditions (Table 1) can be extrapolated to an aquifer having any value of transmissivity. For example, Figures 4 and 6 showing relative concentration versus time, can be extrapolated to any value of transmissivity T^* by multiplying the abscissa by 10^{-3} (ft²/sec)/ T^* . This manipulation requires that the same hydrogeologic conditions—drawdown, hydraulic gradient, and aquifer dispersivity—be maintained. Similarly, Figures 4 and 6 can be extrapolated to any transmissivity under hydrogeologic conditions B and F, the abscissa is first multiplied by a factor of 2 or .6, respectively. Figures 5 and 7, showing relative concentration versus volume of water pumped, are applicable to an aquifer with any value of transmissivity and require no manipulation. Figure 5 is applicable as is for application to hydrogeologic condition B. For application to hydrogeologic condition F, the abscissa in Figure 7 needs to be multiplied by 1.2.

For solutes undergoing linear reversible equilibrium sorption-desorption, the retardation factor, R_F , is defined as the velocity of solute divided by the average linear velocity of the ground water. This retardation factor can be used to estimate the cleanup time for an adsorbed species by multiplying the abscissa by R_F in Figures 4 and 6, assuming no other complicating processes exist.

CONCLUSIONS AND RECOMMENDATIONS

The best well pattern for a ground-water cleanup is highly site-specific and depends upon the objectives and constraints for each problem. The key hydrogeologic variables which control the rate of cleanup are well locations, pumping rates, transmissivity, dispersivity, and hydraulic gradient. For a given set of well locations, by varying transmissivity and maintaining drawdown, dispersivity, and hydraulic gradient constant, the cleanup time is found to be inversely related to the pumping rate.

Seven well patterns were evaluated under different common hydrogeologic conditions on the

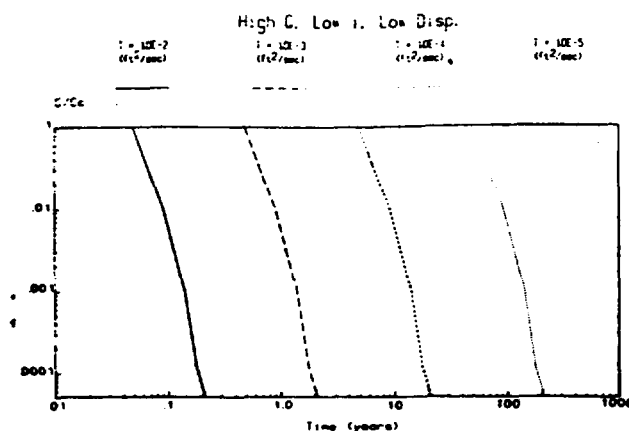


Fig. 9. Application of linearity to a three-spot withdrawal scheme.

basis of cleanup time, volume of water circulated, and volume of water requiring treatment. The following conclusions can be drawn from the analysis: (1) Significant differences in cleanup time were observed using different well locations for a given well pattern. Selecting the well locations with the shortest cleanup time also minimizes the volume of water requiring treatment. (2) The three-spot, doublet, and double-cell well patterns are effective under low hydraulic gradient conditions. These well patterns minimize cleanup time, volume of water circulated and volume of water treated. These well patterns require on-site treatment and reinjection. (3) The three-spot performed better than any of the other well patterns studied under a high hydraulic gradient, high drawdown, and either a low or a high dispersivity. (4) None of the well patterns investigated were able to contain and clean up the contaminant plume under a high gradient, low drawdown, and high dispersivity. (5) The centerline well pattern is effective in achieving up to a 99% level of contaminant reduction under both low and high gradient conditions, but may present a water disposal problem. (6) The five-spot well pattern performed poorly in this study.

Based on this study and conclusions, it is recommended that the three-spot well pattern be considered in the design of an aquifer restoration scheme. When dealing with other sites and different plume sizes and shapes and other complexities including cleanup criteria, constraints, and heterogeneous flow fields, these results may not be applicable and other well patterns should be investigated. In situations where cleanup time is of paramount importance, a combination of the double-triangle and centerline well patterns may be very effective.

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Attachment 5

Alternative No. 3b
Thermal Desorption (10⁻⁶)

Item No.	Description	Capital Costs		Item Cost	Annual Cost
		Quantity	Unit Cost		
1.0	<u>Mobilization</u>				
1.1	Equipment	6 months	\$ 4,000	\$ 24,000	
1.2	Utilities	6 months	1,000	6,000	
1.3	Permits	1 each	10,000	10,000	
1.4	Decon Facilities	6 months	2,500	15,000	
1.5	Air Monitoring	6 months	2,000	12,000	
1.6	Personnel Training	10 each	800	8,000	\$ 1,600
1.7	Photographs	6 months	200	1,200	
1.8	Project Signs	200 each	10	2,000	
1.9	Fencing	8,650 LF	8.50	73,500	1,000
1.10	Monitoring Wells	3 each	10,000	30,000	4,000
1.11	Ground-water Sampling Equipment	1 LS	1,500	1,500	
1.12	Site Office	6 months	1,200	7,200	
1.13	Total Mobilization			\$190,400	\$ 6,600
2.0	<u>Alternate Water Supply</u>				
2.1	Water line, 8-inch	3500 LF	17.80	62,300	4,000
2.2	Residential Service	15 each	620	9,300	2,000
2.3	Repaving	3500 LF	4	14,000	
2.4	Total Alternate Water Supply			\$ 85,600	\$ 6,000
3.0	<u>Ground-Water Monitoring</u>				
3.1	Sampling, twice yearly, 8 wells	-	-	-	20,000
3.2	Lab Analyses/Sampling Period	-	-	-	48,000
	- 16 well samples, 4 QA samples				
	- VOCs, SVOCs, and inorganics				
3.3	Yearly monitoring report	-	-	-	20,000
3.4	Five-year risk analysis	-	-	-	50,000
3.5	Project Administration	-	-	-	96,000
3.6	Total Ground-Water Monitoring				\$234,000

Alternative No. 3b
Thermal Desorption (10⁻⁵)
(Continued)

Item No.	Description	Capital Costs			Annual Cost
		Quantity	Unit Cost	Item Cost	
4.0	<u>Thermal Desorption</u>				
4.1	Mobilization/Demobilization	1 each	50,000	50,000	
4.2	Excavation	8600 CY	10	86,000	
4.3	Feed Preparation	8600 CY	50	430,000	
4.4	Thermal Desorption	8600 CY	200	<u>1,720,000</u>	
4.5	Total Thermal Desorption			\$ 2,286,000	
5.0	<u>Offsite Disposal</u>				
5.1	Includes gate fee, tax, and 250 miles transportation	19,200 ton	200	<u>3,840,000</u>	
5.2	Total Offsite Disposal			\$ 3,840,000	
6.0	<u>Soil Cover</u>				
6.1	Grading/Backfill	3700 CY	4	14,800	
6.2	Import Fill	1100 CY	12	13,200	
6.3	Backfill/Compaction	8600 CY	8	68,800	
6.4	Hydroseed, mulching	0.8 AC	\$ 2,500	2,000	
6.6	Irrigate	10 weeks	400	<u>4,000</u>	
6.7	Total Soil Cover			\$ 102,800	
6.8	Maintenance (10%)				\$ 10,280
7.0	<u>Demobilization</u>				
7.1	Site Restoration	1 each	-	25,000	-
7.2	Administrative Close-Out	1 each	-	<u>5,000</u>	-
7.3	Total Demobilization			\$ 30,000	
	Subtotal Capital Costs			\$6,504,800	
	Total Annual Costs				<u>\$256,800</u>
	Engineering and Design (12%)			780,600	
	Construction Management (10%)			650,500	
	Pilot Studies (6%)			390,300	
	Contingency (30%)			<u>1,951,500</u>	
	Total Capital Costs			<u>\$10,300,000</u>	

Alternative No. 3b
Thermal Desorption (10⁻⁵)
(Continued)

Present-Worth Analysis: $PW = FV [(1 - i)^n]^{-1}$

i = 5 percent

n = 30, 5

n = 30 years

$$\begin{aligned} PW &= \$10,300,000 + \$206,900 (P/A \ 5,30) + \$50,000 (P/F \ 5,5) \\ PW &= \$10,300,000 + \$206,900 (15.372) + \$50,000 (2.782) \\ PW &= \$13,600,000 \end{aligned}$$

n = 5 years

$$\begin{aligned} PW &= \$10,300,000 + \$206,900 (P/A \ 5,5) + \$50,000 (P/F \ 5,5) \\ PW &= \$10,300,000 + \$206,900 (4.329) + \$50,000 (0.7835) \\ PW &= \$11,200,000 \end{aligned}$$

Note: Actual costs may vary from -30 to +50 percent of values presented based on uncertainties in rate and cost factors. Additional variations in costs may also be realized based on uncertainties related to estimates of volume or area. Verification sampling conducted during the remedial design phase will be necessary to refine these estimates.

Alternative No. 3b
Thermal Desorption (10⁻⁴)

Item No.	Description	Capital Costs			Annual Cost
		Quantity	Unit Cost	Item Cost	
0	<u>Mobilization</u>				
1.1	Equipment	6 months	\$ 4,000	\$ 24,000	
1.2	Utilities	6 months	1,000	6,000	
	Permits	1 each	10,000	10,000	
	Decon Facilities	6 months	2,500	15,000	
	Air Monitoring	6 months	2,000	12,000	
	Personnel Training	10 each	800	8,000	\$ 1,600
1.7	Photographs	6 months	200	1,200	
1.8	Project Signs	200 each	10	2,000	
1.9	Fencing	8,650 LF	8.50	73,500	1,000
1.10	Monitoring Wells	3 each	10,000	30,000	4,000
1.11	Ground-water Sampling Equipment	1 LS	1,500	1,500	
1.12	Site Office	6 months	1,200	7,200	
1.13	Total Mobilization			\$190,400	\$ 6,600
0	<u>Alternate Water Supply</u>				
2.1	Water line, 8-inch	3500 LF	17.80	62,300	4,000
2.2	Residential Service	15 each	620	9,300	2,000
3	Repaving	3500 LF	4	14,000	
	Total Alternate Water Supply			\$ 85,600	\$ 6,000
0	<u>Ground-Water Monitoring</u>				
3.1	Sampling, twice yearly, 8 wells	-	-	-	20,000
3.2	Lab Analyses/Sampling Period	-	-	-	48,000
	- 16 well samples, 4 QA samples				
	- VOCs, SVOCs, and inorganics				
3.3	Yearly monitoring report	-	-	-	20,000
3.4	Five-year risk analysis	-	-	-	50,000
3.5	Project Administration	-	-	-	96,000
3.6	Total Ground-Water Monitoring				\$234,300

APPENDIX M

Alternative No. 3b
Thermal Desorption (10⁻⁴)
 (Continued)

Item No.	Description	Capital Costs			Annual Cost
		Quantity	Unit Cost	Item Cost	
4.0	<u>Thermal Desorption</u>				
4.1	Mobilization/Demobilization	1 each	50,000	50,000	
4.2	Excavation	4800 CY	10	48,000	
4.3	Feed Preparation	4800 CY	50	240,000	
4.4	Thermal Desorption	4800 CY	200	<u>960,000</u>	
4.5	Total Thermal Desorption			\$ 1,298,000	
5.0	<u>Offsite Disposal</u>				
5.1	Includes gate fee, tax, and 250 miles transportation	11,000 ton	200	<u>2,200,000</u>	
5.2	Total Offsite Disposal			\$ 2,200,000	
6.0	<u>Soil Cover</u>				
6.1	Grading/Backfill	3100 CY	4	12,400	
6.2	Import Fill	1100 CY	12	13,200	
6.3	Backfill/Compaction	5800 CY	8	46,400	
6.4	Hydroseed, mulching	0.8 AC	\$ 2,500	2,000	
6.6	Irrigate	10 weeks	400	<u>4,000</u>	
6.7	Total Soil Cover			\$ 78,000	
6.8	Maintenance (10%)				\$ 7,800
7.0	<u>Demobilization</u>				
7.1	Site Restoration	1 each	-	25,000	-
7.2	Administrative Close-Out	1 each	-	<u>5,000</u>	-
7.3	Total Demobilization			\$ 30,000	
	Subtotal Capital Costs			\$1,682,100	
	Total Annual Costs				<u>\$254,400</u>
	Engineering and Design (12%)			462,200	
	Construction Management (10%)			385,200	
	Pilot Studies (6%)			231,100	
	Contingency (30%)			<u>1,155,600</u>	
	Total Capital Costs			<u>\$6,086,200</u>	

Alternative No. 3b
Thermal Desorption (10⁻⁴)
(Continued)

Present-Worth Analysis: $PW = FV [(1 - i)^n]^{-1}$

i = 5 percent

n = 30, 5

n = 30 years

PW = \$6,086,200 + \$204,400 (P/A 5,30) + \$50,000 (P/F 5,30)
PW = \$6,086,200 + \$204,400 (15.372) + \$50,000 (2.782)
PW = \$9,400,000

n = 5 years

PW = \$6,086,200 + \$204,400 (P/A, 5,5) + \$50,000 (P/F 5,5)
PW = \$6,086,200 + \$204,400 (4.329) + \$50,000 (0.7835)
PW = \$7,010,200

Alternative No. 2a
Soil Cover (10^{-5} , 10^{-6})*

Item No.	Description	Capital Costs			Annual Cost
		Quantity	Unit Cost	Item Cost	
<u>Mobilization</u>					
1.1	Equipment	2 months	\$ 4,000	\$ 8,000	
1.2	Utilities	2 months	1,000	2,000	\$ 1,000
1.3	Permits	0 each	0	0	
1.4	Decon Facilities	2 months	2,500	5,000	
1.5	Air Monitoring	2 months	2,000	4,000	
1.6	Personnel Training	5 each	800	4,000	1,600
1.7	Photographs	2 months	200	400	
1.8	Project Signs	200 each	10	2,000	
1.9	Fencing	8,650 LF	8.50	73,500	1,000
1.10	Monitoring Wells	3 each	10,000	30,000	4,000
1.11	Ground-water Sampling Equipment	1 LS	1,500	1,500	
1.12	Site Office	2 months	1,200	2,400	
1.13	Total Mobilization			\$132,800	\$ 7,600
<u>Alternate Water Supply</u>					
2.1	Water Line, 8-inch	3,500 LF	17.80	62,300	4,000
2.2	Residential Services	15 ea.	620	9,300	2,000
2.3	Repaving	3,500 LF	4.00	14,000	
2.4	Hydrant	1	750	750	
2.5	Total Alternate Water Supply			\$ 86,400	\$ 6,000
<u>Ground-Water Monitoring</u>					
3.1	Sampling, twice yearly, 8 wells	-	-	-	20,000
3.2	Lab Analyses/Sampling Period - 16 well samples, 4 QA samples - VOCs, SVOCs, and inorganics	-	-	-	48,000
3.3	Yearly monitoring report	-	-	-	20,000
3.4	Five-year risk analysis	-	-	-	50,000
3.5	Project Administration	-	-	-	96,000
3.6	Total Ground-Water Monitoring				\$234,000

Alternative No. 2a
Soil Cover (10⁻⁵, 10⁻⁶)*
 (Continued)

Item No.	Description	Capital Costs			Annual Cost
		Quantity	Unit Cost	Item Cost	
<u>Soil Cover</u>					
4.1	Clear and Strip	3700 SY	1	3,700	
4.2	Grading	3700 SY	4	14,800	
4.3	Import Fill	1100 CY	12	13,200	
4.4	Backfill/Compaction	3700 SY	8	29,600	
4.5	Hydroseed, mulching	0.8 AC	\$ 2,500	2,000	
4.6	Irrigate	10 weeks	400	4,000	
4.7	Total Soil Cover			\$ 67,300	
4.8	Maintenance (10%)				\$ 6,730
	Subtotal Capital Costs			\$286,500	
	Total Annual Costs				<u>\$254,300</u>
	Engineering and Design (12%)			34,380	
	Construction Management (10%)			28,650	
	Contingency (30%)			<u>86,000</u>	
	Total Capital Costs			<u>\$435,400</u>	

Present-Worth Analysis: $PW = FV [(1 - i)^n]^{-1}$

i = 5 percent

n = 5, 30

n = 30 years

$$PW = \$435,400 + \$204,300 (P/A 5,30) + \$50,000 (P/F 5,30)$$

$$PW = \$435,400 + \$204,300 (15.372) + \$50,000 (2.782)$$

$$PW = \$3,715,500$$

n = 5 years

$$PW = \$435,400 + \$204,300 (P/A 5,5) + \$50,000 (P/F 5,5)$$

$$PW = \$435,400 + \$204,300 (4.329) + \$50,000 (0.7835)$$

$$PW = \$1,360,000$$

10⁻⁵ and 10⁻⁶ costs are identical because a differential in the quantity of material to be treated cannot be distinguished at this time. Upon verification sampling, a differential may be observed in which case these costs should be revised.

Notes: Actual costs may vary from -30 to +50 percent of values presented based on uncertainties in rate and cost factors. Additional variations in costs may also be realized based on uncertainties related to estimates of volume or area. Verification sampling conducted during the remedial design phase will be necessary to refine these estimates.

Alternative No. 1
No Further Action (10^{-4} , 10^{-5} , 10^{-6})

Item No.	Description	Capital Costs		Annual Cost
		Quantity	Unit Cost	
1.0	<u>Mobilization</u>			
1.1	Equipment	1 month	\$ 4,000	\$ 4,000
1.2	Utilities	1 month	1,000	1,000
1.3	Permits	0 each	0	0
1.4	Decon Facilities	1 month	2,500	2,500
1.5	Air Monitoring	1 month	2,000	2,000
1.6	Personnel Training	2 each	800	1,600
1.7	Photographs	1 month	200	200
1.8	Project Signs	200 each	10	2,000
1.9	Fencing	8,650 LF	8.50	73,500
1.10	Monitoring Wells	3 each	10,000	30,000
1.11	Ground-water Sampling Equipment	1 LS	1,500	1,500
1.12	Site Office	1 month	1,200	1,200
1.13	Total Mobilization			\$119,500
2.0	<u>Ground-Water Monitoring</u>			
2.1	Sampling, twice yearly, 8 wells	-	-	20,000
2.2	Lab Analyses/Sampling Period	-	-	48,000
	- 16 well samples, 4 QA samples			
	- VOCs, SVOCs, and inorganics			
2.3	Yearly monitoring report	-	-	20,000
2.4	Five year risk analysis	-	-	50,000
2.5	Project Administration	-	-	72,000
2.6	Total Ground-Water Monitoring			\$210,000
	Subtotal Capital Costs		\$119,500	
	Total Annual Costs			<u>\$217,600</u>
	Engineering and Design (12%)		14,340	
	Construction Management (10%)		11,950	
	Contingency (30%)		<u>\$ 35,900</u>	
	Total Capital Costs		<u>\$181,700</u>	

Alternative No. 1
No Further Action (10^{-4} , 10^{-5} , 10^{-6})
(Continued)

<u>Item No.</u>	<u>Description</u>	<u>Capital Costs</u>		<u>Item Cost</u>	<u>Annual Cost</u>
		<u>Quantity</u>	<u>Unit Cost</u>		

Present-Worth Analysis: $PW = FV [(1 - i)^n]^{-1}$

$i = 5$ percent

$n = 30, 5$

$n = 30$ years

$$PW = \$181,700 + \$167,600 (P/A \ 5, 30) + \$50,000 (P/F \ 5, 30)$$

$$PW = \$181,700 + \$167,600 (15.372) + \$50,000 (2.782)$$

$$PW = \$2,900,000$$

$n = 5$ years

$$PW = \$181,700 + \$167,600 (P/A \ 5, 5) + \$50,000 (P/F \ 5, 5)$$

$$PW = \$181,700 + \$167,600 (4.329) + \$50,000 (0.7835)$$

$$PW = \$950,000$$

Note: Actual costs may vary from -30 to +50 percent of values presented based on uncertainties in rate and cost factors.

Alternative No. 2a
Soil Cover (10⁻⁴)

Item No.	Description	Capital Costs		Item Cost	Annual Cost
		Quantity	Unit Cost		
1.0	<u>Mobilization</u>				
1.1	Equipment	2 months	\$ 4,000	\$ 8,000	
1.2	Utilities	2 months	1,000	2,000	\$ 1,000
1.3	Permits	0 each	0	0	
1.4	Decon Facilities	2 months	2,500	5,000	
1.5	Air Monitoring	2 months	2,000	4,000	
1.6	Personnel Training	5 each	800	4,000	1,600
1.7	Photographs	2 months	200	400	
1.8	Project Signs	200 each	10	2,000	
1.9	Fencing	8,650 LF	8.50	73,500	1,000
1.10	Monitoring Wells	3 each	10,000	30,000	4,000
1.11	Ground-water Sampling Equipment	1 LS	1,500	1,500	
1.12	Site Office	2 months	1,200	<u>2,400</u>	
1.13	Total Mobilization			\$132,800	\$ 7,600
2.0	<u>Alternate Water Supply</u>				
2.1	Water Line, 8-inch	3,500 LF	17.80	62,300	4,000
2.2	Residential Services	15 ea.	620	9,300	2,000
2.3	Repaving	3,500 LF	4.00	14,000	
2.4	Hydrant	1	750	<u>750</u>	
2.5	Total Alternate Water Supply			\$ 86,400	\$ 6,000
3.0	<u>Ground-Water Monitoring</u>				
3.1	Sampling, twice yearly, 8 wells	-	-	-	20,000
3.2	Lab Analyses/Sampling Period	-	-	-	48,000
	- 16 well samples, 4 QA samples				
	- VOCs, SVOCs, and inorganics				
3.3	Yearly monitoring report	-	-	-	20,000
3.4	Five-year risk analysis	-	-	-	50,000
3.5	Project Administration	-	-	-	<u>96,000</u>
3.6	Total Ground-Water Monitoring				\$234,000

Alternative No. 2a
Soil Cover (10⁻⁴)
(Continued)

		<u>Capital Costs</u>		
	<u>Description</u>	<u>Quantity</u>	<u>Unit Cost</u>	<u>Item Cost</u>
<u>Soil Cover</u>				
1	Clear and Strip	3200 SY	1	3,200
2	Grading	3200 SY	4	12,800
3	Import Fill	900 CY	12	10,800
4	Backfill/Compaction	3200 SY	8	25,600
5	Hydroseed, mulching	0.8 AC	\$ 2,500	2,000
6	Mow/Edge	10 weeks	<u>400</u>	<u>4,000</u>
7	Total Soil Cover			\$ 58,400
8	Maintenance (10%)			\$ 5,840
Subtotal Capital Costs				\$277,600
Total Annual Costs				<u>\$253,440</u>
Engineering and Design (12%)				33,310
Construction Management (10%)				27,760
Contingency (30%)				<u>83,300</u>
Total Capital Costs				<u>\$421,900</u>

Present Worth Analysis: $PW = FV [(1 - i)^n]^{-1}$

i = 5 percent

n = 5, 30

n = 30 years

PW = \$421,900 + \$203,440 (P/A 5,30) + \$50,000 (P/F 5,30)

PW = \$421,900 + \$203,440 (15.372) + \$50,000 (2.782)

PW = \$3,700,000

n = 5 years

PW = \$421,900 + \$203,440 (P/A 5,5) + \$50,000 (P/F 5,5)

PW = \$421,900 + \$203,440 (4.329) + \$50,000 (0.7835)

PW = \$1,340,000

Actual costs may vary from -30 to +50 percent of values presented based on uncertainties in rate and cost factors. Additional variations in costs may also be realized based on uncertainties related to estimates of volume or area. Verification sampling conducted during the remedial design phase will be necessary to refine these estimates.

Attachment 6

INTER-OFFICE MEMORANDUM

To: Laurel Staley, RREL Date: October 9, 1990

From: Mike Johnson, PRC *MAJ*

Subject: Recycling Sciences International, Inc. (RSI) SITE Demonstration --
Results of Waukegan Harbor Treatability Tests

As you recently requested, I have gathered available information concerning the treatability tests conducted by Recycling Sciences International, Inc. (RSI) (formerly American Toxics Disposal -- ATD). In 1984 and 1985, RSI conducted 13 treatability tests on sediments obtained from Waukegan (Illinois) Harbor and the Hudson River. The duration of the tests ranged from 0.5 hours to 5.5 hours and the sediment quantities treated ranged from 241 pounds to 5,762 pounds. The results of the tests are summarized in Attachment 1.

Attachment 2 presents a detailed project summary of the treatability tests. The project summary describes the operating parameters, summarizes the test data, and presents a rough mass balance for the system. Please note that RSI has made substantial improvements to its equipment since these tests were conducted. These improvements include installing (1) a waste feed system with a nominal feed rate of 8.5 tons per hour (based on 85 percent solids in the feed), (2) a second vapor phase carbon bed in series with a backup carbon bed, and (3) a more extensive liquid processing system, including a centrifuge and pressure filter system preceding two carbon beds arranged in series.

If you have any questions concerning the treatability tests, please call me at (312) 856-8700.

cc: Karla Auker, Ohio EPA/NEDO
Joe Heimbuch, Technical Environmental Consultants, Inc.
Mike Percival, Technical Environmental Consultants, Inc.
Dave Cowgill, U.S. EPA, Great Lakes National Program Office
John Piper, U.S. EPA, Great Lakes National Program Office
Rick Fox, U.S. EPA, Great Lakes National Program Office
Jonathan Herrmann, RREL
Dennis L. Timberlake, RREL
Mark Meckes, RREL
Ken Kastman, Woodward-Clyde
Canar Zambek, Woodward-Clyde
Peter Sanders, U.S. EPA Region 5

ATTACHMENT 1

**RESULTS OF PILOT-SCALE TESTS AT
WAUKEGAN HARBOR AND THE HUDSON RIVER**

<u>Date</u>	<u>Duration Hours</u>	<u>Amount of Clean Solids lbs.</u>	<u>Feed PCB Concentration</u>	<u>Concentration in Clean Solids Discharge, ppm</u>
7-19-84	1.5	241	44	1.6
8-27-84	1.25	2444	109	1.0
8-29-84	0.5	823	53	1.5
8-30-84	1.5	2470	37	3.2
9-04-84	3.75	5762	31	0.9
9-10-84	5.0	5704	38	1.5
9-11-84	5.5	4932	28	4.0
9-12-84	1.0	823	27	1.4
3-12-85	1.25	2450	12.8	0.5
3-15-85	3.0	2733	12.9	0.5
3-26-85	2.0	433	8.6	1.3
3-27-85	3.75	1531	8.6	1.3
4-18-85	3.5	1490	206	0.8

Notes: The average PCB concentration (\bar{x}) in the clean solids discharge equals 1.89 ppm. The population standard deviation (σ) equals 1.11 ppm.

ATTACHMENT 2

TEST DATA/PERFORMANCE CALCULATIONS

The mobil Vaporization Extraction System (VES) developed by ATD utilizes a roller mill unit with a modified, rotating, fluidized bed. This unit (V1) receives the host material containing PCB. Hot contact gas from an air heater is injected into the bed, at controlled temperatures (320°F), causing the PCB to leave the host material in a gas phase which is contained in ducted piping. The products of the volatilization are processed, so that the toxic hydrocarbons are captured and concentrated for EPA approved disposal.

The VES unit was first assembled for testing at a site in Waukegan, Illinois, where it had been approved by the EPA for test processing of PCB-contaminated sludge dredged from Slip No. 3 of the Waukegan Harbor. After completion of the construction phase and tests with non-toxic material at Waukegan, ATD began a series of tests using the PCB-contaminated sludge. The first series of tests were called "The Summer Series 1984," running from July 19, 1984 to September 12, 1984. Eight test runs were accomplished, processing approximately 15.5 tons of sludge. The next test series, known as "The Spring Series 1985," was begun on March 12, 1985 and consisted of 5 toxic tests using Waukegan Harbor material (March 12 - 15), Hudson River material (March 26 - 27), and an EPA-approved spike test on April 18, 1985. The following sections describe the tests and results.

A summary of test data from the Waukegan operations is presented in Appendix G. Full data on these tests is contained in a supplemental volume entitled "Vaporization Extraction System Tests, 1984-85, Waukegan, Illinois."

A. SUMMER SERIES 1984 TESTS

On October 18, 1982 approval was given (and subsequently extended) from the EPA to proceed with a pilot project by testing the process with up to 25 tons of PCB-contaminated sludge to be dredged from Slip No. 3 in Waukegan Harbor, Waukegan, Illinois. Tests were subsequently conducted in Waukegan using a portable unit mounted on a truck or barge. Maximum capacity of this unit was 10 tons per hour. The tests included multiple short duration and longer duration runs. Chemical analyses were made on the sludge before testing and in the solids discharged after processing. Prior to processing, the sludge had PCB concentrations of up to 250 ppm; after processing, the sludge contained less than 2 ppm of PCBs.

The findings and conclusions from these tests were included in an official report to the U.S. EPA and the Illinois EPA. Supported by documentation of the independently performed chemical testing procedures, ATD believes the report proved the technical and environmental viability of the patented VES process.

July 19, 1984. After the successful start-up of the unit with non-toxic material, the first series of tests with toxic sludge extracted from Waukegan Harbor began on July 19, 1984. This test lasted 11 hours and the total amount of material processed was 3000 lbs. (wet). Approximately 70 gallons of water was processed and discharged into the dirty water storage tank.

During the test, the contact gas temperature averaged 1000°F, and the bed temperature averaged 325°F. The system operated at a negative pressure of .32"W.C. and a gas flow rate of 5800 lb/hr. The inlet and outlet of the V6 carbon adsorber were constantly monitored using the approved Modified Method 5 sample train. A sample of the system water was taken at the final gas wash outlet (sample No. 40705867). A sample of incoming sludge was taken (sample No. 40765) and showed a PCB concentration of 44 MG/KG. A sample of the solids discharge was taken (sample No. 40774) and showed a PCB-concentration of 1.6 MG/KG. The coarse solids discharge on this date was 2470 lbs. 2% went overhead as fines (50.4 lbs.). A sample of these fines was taken (No. 40778) and contained 102 MG/KG. All processed material was placed in EPA approved containers and stored in a bermed area.

August 27, 1984. The next toxic test was done on August 27, 1984. This test lasted 75 minutes with a total of 3000 lbs. (wet) of contaminated material processed. Approximately 70 gallons of water was processed and discharged into the dirty water storage tank.

During the test, the contact gas temperature averaged 1400 °F and the bed temperature averaged 325°F. The system operated at a negative pressure of .30"W.C. and a gas flow of 6000 lb/hr. The inlet and the outlet of the V6 carbon adsorber were constantly monitored using the approved Modified Method 5 sample train. A sample of the system water was not taken at the scrubber outlet. A sample of incoming sludge was taken (sample No. 40842) and showed a PCB concentration of 109 MG/KG. A sample of the solids discharge was taken (sample No. 40841) and showed a PCB concentration of 1.0 MG/KG. The coarse solids discharge was 2444 lbs. 3% went overhead as fines (75lbs). The fines were not analyzed. All processed material was placed in EPA approved containers and stored in a bermed area.

August 29, 1984. The next toxic test was done on August 29, 1984. After 30 minutes, the test was discontinued because of a

defective belt on the spinner separator. The total material processed was 1000 lbs. (wet). Approximately 20 gallons of water was processed and discharged into the dirty water storage tank.

During the test the average contact gas temperature was 1400°F and the average bed temperature was 300°F. The system operated at a negative .22"W.C. and a gas flow of 5600 lb/hr. The inlet and outlet of the V6 carbon adsorber were constantly monitored, using the approved Modified Method 5 sample train. A sample of incoming sludge was taken (sample No. 40856) and showed a PCB concentration of 53 MG/KG. A sample of the solids discharge was taken on sample No. 40864 and showed a PCB concentration of 1.5 MG/KG. The coarse solids discharge on this date was 823 lbs. 2½ went overhead as fines (16.8 lbs.). A sample (No. 40865) was taken of these fines and contained 36 MG/KG of Aroclor 1248. All processed material was placed in EPA approved containers and stored in a bermed area.

August 30, 1984. The next toxic test was done on August 30, 1984. This test lasted 90 minutes with a total of 3000 lbs. (wet) of contaminated material processed. The dry weight of the coarse discharge material was 2470 lbs.

Approximately 70 gallons of water was processed and discharged into the dirty water storage tank. During the tests, the contact gas temperature averaged 1500 °F and the bed temperature averaged 350°F. The system operated at a negative pressure of .20"W.C. and a gas flow rate of 5500 lb/hr. The inlet and outlet of the V6 carbon adsorber were constantly monitored using the approved Modified Method 5 sample train. A sample of the incoming sludge was taken (No. 80 mpa) and showed a concentration of 37 MG/KG of PCBs. A sample of the coarse solids discharge was taken (No. 83 mpa) and showed a PCB concentration of 3.2 MG/KG. The total coarse solids discharge was 2470 lbs. 2½ went overhead as fines (50.4 lbs.). A sample of the fines was analyzed (sample No. 86 mpa). The PCB concentration was 9 MG/KG. All processed material was placed in EPA approved containers and stored in a bermed area.

September 4, 1984. The next toxic test was done on September 4, 1984. This test lasted 3.75 hours. The total material processed was 7000 lbs. (wet). The dry weight of the coarse discharge material was 5600 lbs. and approximately 165 gallons of water was processed and discharged into the dirty water storage tank.

During the tests the contact gas temperature averaged 1600°F and the bed temperature averaged 350°F. The system operated at a negative pressure of .30"W.C. and a gas flow rate of 6000 lb/hr. The inlet and outlet of the V6 carbon adsorber were constantly monitored, using the approved Modified Method 5 sample train. A sample of the incoming sludge was taken (Sample No. 40912). A concentration of 31 MG/KG was recorded. A sample of the coarse

solids discharge was taken on sample No. 40917 and showed a PCB concentration of .9 MG/KG. The total solids discharge was 5762 lbs. Of that amount 2½ went overhead as fines (118 lbs). A sample of the fines was analyzed (sample No. 40918) with the recorded PCB concentration being 21 MG/KG. All processed material was placed in EPA approved containers and stored in a bermed area.

September 10, 1984. The next toxic test was done on September 10, 1984. This test lasted 5 hours. The total material processed was 7000 lbs. (wet). Approximately 120 gallons of water was processed and discharged into the dirty water storage tank.

During the tests the contact gas temperature averaged 1450°F and the bed temperature averaged 375°F. The system operated at negative pressure of .30"W.C. and a gas flow rate of 6100 lb/hr. The inlet and outlet of the V6 carbon adsorber were constantly monitored using the approved Modified Method 5 sample train. A sample of the incoming sludge was taken (No. 40931) with analysis showing a concentration of 38 MG/KG. A sample of the solids discharge was taken (sample No. 40993) and showed a PCB concentration of 1.5 MG/KG. The coarse solids discharge was 5794 lbs. 3½ went overhead as fines (176 lbs.). The fines were not analyzed. All processed material was placed in EPA approved containers and stored in a bermed area.

September 11, 1984. The next toxic test was done on September 11, 1984. This test lasted 5.5 hours to 3:30 p.m. The total material processed was 6000 lbs. (wet). The dry weight of the coarse discharge material was 4932 lbs. Approximately 140 gallons of water was processed and discharged into the dirty water storage tank.

During the tests the contact gas temperature averaged 1500°F and the bed temperature averaged 400°F. The system operated at a negative pressure of .20"W.C. and a gas flow rate of 6100 lb/hr. The inlet and outlet of the V6 carbon adsorber were constantly monitored using the approved Modified Method 5 sample train. A sample of the incoming sludge was taken (sample No. 40957) and a concentration of 28 MG/KG was recorded. A sample of the coarse solids discharge was taken (sample No. 40994) and showed a PCB concentration of 4.0 MG/KG. The total coarse solids discharge was 4932 lbs. Of that amount 2½ went overhead as fines (101 lbs.). The fines were not analyzed. All processed material was placed in EPA approved containers and stored in a bermed area.

September 12, 1984. The next toxic test was done on September 12, 1984. This test lasted 1 hour with a total of 1000 lbs. (wet) of material processed. The dry weight of the coarse discharge was 1000 lbs. Approximately 24 gallons of water was processed and discharged into the dirty water storage tank.

During the tests the contact gas temperature averaged 1600°F and the bed temperature averaged 300°F. The system operated at a negative pressure of .25"W.C. and a gas flow rate of 5600 lb/hr. The inlet and outlet of the V6 carbon adsorber were constantly monitored using the approved Modified Method 5 sample train. A sample of the incoming sludge was taken (No. 40983) and showed a concentration of 27 MG/KG. A sample of the solids discharge was taken (sample No. 40995) and showed a PCB concentration of 1.4 MG/KG. The coarse solids discharge was 823 lbs.; 2% went overhead as fines (16.8 lbs.). The fines were not analyzed. All processed material was placed in EPA approved containers and stored in a bermed area.

B. SUMMER SERIES 1985 TESTS

The Summer, 1985 series of tests included processing of Waukegan Harbor sludge as well as sludge transported from the Hudson River in New York. Testing was monitored by officials from the U.S. EPA, the Illinois EPA and the New York Department of Environmental Conservation.

March 12, 1985. The first toxic test was done on March 12, 1985. This test lasted 1 hour and 15 minutes. The total material processed was 2940 lbs. Approximately 60 gallons of water was processed and discharged into the dirty water storage tank.

During the tests, the contact gas temperature averaged 1500°F. The average bed temperature was 325°F. The system operated at a negative of .18"W.C. and a gas flow rate of 5700 lb./hr. The inlet and outlet of the V6 carbon adsorber were constantly monitored, using the approved Modified Method 5 sample train. A sample of the system water was taken at the gas wash outlet by Allied Laboratories Ltd. A concentration of 0.5 ppm was reported. A sample of the incoming sludge was taken. A concentration of 12.5 ppm was recorded. A sample of the coarse solids discharge showed PCB concentrations of 0.5 ppm. The total solids discharge was 2450 lbs. 5% went overhead as fines (123 lbs.). A sample of fines was analyzed and showed a PCB concentration of 2.3 ppm. All processed material was placed in EPA approved containers and stored in a bermed area.

March 15, 1985. The next toxic test was done on March 15, 1985. This test lasted 3 hours. The total material processed was 3279 lbs. (wet). The dry weight of the coarse discharge material was 2733 lbs. Approximately 64 gallons of water was processed and discharged into the dirty water storage tank.

During the tests, the contact gas temperature averaged 1450°F and the average bed temperature was 275°F. The system operated at a

negative pressure of .30"W.C. and a gas flow rate of 5800 lb/hr. The inlet and outlet of the V6 carbon adsorber were constantly monitored, using the approved Modified Method 5 sample train. A sample of the incoming sludge showed a PCB concentration of 12.9 ppm. A sample of the coarse solids discharge was taken. The PCB concentration was .5 ppm. The total coarse solids discharge was 2733 lbs. 2.5% (approximately 70 lbs.) went overhead as fines. The PCB concentration was 2.0 ppm. All processed material was placed in EPA approved containers and stored in a bermed area.

March 26, 1985. The next toxic test was done on March 26, 1985. The New York Department of Environmental Conservation dredged 10 tons of PCB-contaminated sludge from the Hudson River and transported it to Waukegan, Illinois for processing in ATD's pilot test facility at the Waukegan Harbor.

The March 26 test lasted 2 hours. The total material processed was 680 lbs. (wet). The dry weight of the coarse discharge material was 437 lbs. 13 gallons of water was processed and discharged into the dirty water storage tank.

During the test, the contact gas temperature averaged 1200°F, the bed temperature averaged 270°F. The system operated at a negative pressure of .25"W.C. and a gas flow rate of 4500 lb/hr. The inlet and outlet of the V6 carbon adsorber were constantly monitored, using the approved Modified Method 5 sample trains. A sample of the incoming sludge was taken (No. 12499). A concentration of 8.6 ppm was recorded. A sample of the coarse solids discharge was taken (No. 12499) The PCB concentration was 1.3 ppm. The total solids discharge was 544 lbs. Of that, 20% (107 lbs.) went overhead as fines. A sample of fines was analyzed (No. 12499). The PCB concentration was 1.0 ppm. All processed material was placed in EPA approved containers and stored in a bermed area.

March 27, 1985. The next test using Hudson River material was done on March 27, 1985. This test lasted 3-3/4 hours. The total material processed was 1966 lbs. (wet). The dry weight of the coarse solids discharge material was 1531 lbs. 49.15 gallons of water was processed and discharged into the dirty water storage tank.

During the tests, the contact gas temperature averaged 1500°F and the average bed temperature was 275°F. The system operated at a negative of .31"W.C. and a gas flow rate of 5900 lb/hr. The inlet and outlet of the V6 carbon adsorber were constantly monitored, using the approved Modified Method 5 sample train. A sample of the incoming sludge was taken. A concentration of 8.6 ppm was recorded. A sample of the coarse solids discharge was taken. The PCB concentration was 1.3 ppm. The total coarse solids discharge was 1531 lbs. Of that 6.0% (108 lbs.) went overhead as fines. The fines were not analyzed. All processed

material was placed in EPA approved containers and stored in a bermed area.

April 18, 1985. The next toxic test was done April 18, 1985. This test was an EPA Region V approved "Spike" of a quantity of "clean" Waukegan Harbor sludge with a known quantity of aroclor 1248. The object of this test was to determine the process capability for removing PCB at higher concentrations (887 ppm).

Approximately 2000 lbs. of clean material from the south harbor was thoroughly mixed with 1 pt. of liquid designated as aroclor 1248. This mixture was placed in the ATD feed hopper. This test lasted 3½ hours. The total material processed was 2000 lbs. (wet). The dry weight of the coarse solids discharge was 1645 lbs. Approximately 18 gallons of water was processed and discharged into the dirty water storage tank (90% solids feed).

During the tests, the contact gas temperature averaged 1400°F and the average bed temperature was 275°F. The system operated at a negative pressure of .31"W.C. and a gas flow rate of 4800 per hour. The inlet and the outlet of the V6 carbon adsorber were constantly monitored using the approved Modified Method 5 sample train. Samples of the incoming sludge were taken. Tests of these samples showed a range of from .8 to 18 ppm. Samples of the fines were taken from a total fines discharge of 154 lbs. Tests of these samples showed a range from 7 to 82 ppm. All processed material was placed in EPA approved containers and stored in a bermed area.

C. SUMMARY OF TEST DATA

A summary of test data from the Summer Series 1984 tests and the Spring Series 1985 tests

SUMMARY OF ATD'S 13 PCB TESTS

After the completion of the construction phase and tests with non-toxic material at Waukegan, IL, ATD began a series of tests using PCB contaminated sludge. The first series of tests were called "The Summer Series 1984." They ran from July 19, 1984 to September 12, 1984. Eight test runs were accomplished, processing approximately 15.5 tons of sludge extracted from Waukegan Harbor, Waukegan, IL. The next test series was begun on March 12, 1985 (The Spring Series 1985) and consisted of 5 toxic tests using Waukegan Harbor material (March 12-15) Hudson River material (March 26-27) and an EPA approved spike test of 4-18-85. The following is a summary of these tests demonstrating PCB concentrations in input and coarse solids discharges as well as the dry weight of discharges of solids and captive fines.

TEST SUMMARY DATA

<u>TEST NO. II-</u>	<u>DATE</u>	<u>DURATION HRS</u>	<u>LBS OF DISCHARGE COARSE</u>	<u>PRODUCT DISCHARGE FINES</u>	<u>PPM FEED</u>	<u>PCB, DRY COARSE SOLIDS DISCHARGE</u>
	1984					
A	7-19	1.5	2410	50.4	44	1.6
B	8-27	1.25	2444	75	109	1.0
C	8-29	0.5	823	16.8	53	1.5
D	8-30	1.5	2470	50.4	37	3.2
E	9-04	3.75	5762	118	31	0.9
F	9-10	5.0	5704	176	38	1.5
G	9-11	5.5	4932	101	28	4.0
H	9-12	1.0	823	168	27	1.4
	1985					
J	3-12	1.25	2450	123	12.8	0.5
K	3-15	3.0	2733	70	12.9	0.5
L	3-26	2.0	437	107	8.6	1.3
M	3-27	3.75	1531	108	8.6	1.3
						0.8

II-2

REPORT ON SYSTEM OPERATING PARAMETERS SUMMER SERIES 1984

TEST DATE	7/19	8/27	8/29	8/30	9/04	9/10	9/11	9/12
AVERAGE BED HT. 1	6"	9"	8"	8"	11"	12"	10"	9"
AVERAGE CONTACT GAS TEMP. 2	1000°F	1400°F	1400°F	1500°F	1600°F	1450°F	1500°F	1600°F
AVERAGE BED TEMP. 3	325°F	325°F	300°F	350°F	350°F	375°F	400°F	300°F
GAS FLOW, PPH 4	5800	6000	5600	5500	6000	6100	6100	5600
LENGTH OF RUN, EFF. 5	1.5 hr.	1.25 hr.	.5 hr.	1.5 hr.	3.75 hr.	5 hr.	5.5 hr.	1 hr.
EXTRACTOR R.P.M. 6	15	15	15	18	22	22	20	20
VG ADSORB. INLET TEMP. 7	85°F	85°F	85°F	87°F	85°F	85°F	85°F	85°F
8								
9								
10								
11								
12								
13								
14								
15								
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23								
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25								
26								
27								
28								
29								

REPORT ON SYSTEM OPERATING PARAMETERS .

REPORT ON SYSTEM OPERATING PARAMETERS .

SPRING SERIES 1985

TEST DATE	3/12	3/15	3/26	3/27	4/18				
AVERAGE BED HT. ¹	8"	4"	7"	4"	4"				
AVERAGE CONTACT GAS TEMP. ²	1500°F	1450°F	1200°F	1500°F	1400°F				
AVERAGE BED TEMP. ³	325°F	275°F	270°F	275°F	275°F				
GAS FLOW, P. H. ⁴	5700	5800	4500	5900	5800				
LENGTH OF RUN, HRS. ⁵	1.25	3	2	3.5	3.5				
EXTRACTOR R. P. M. ⁶	18	18	18	10	18				
V6 ADSORB INLET TEMP. ⁷	85°F	85°F	85°F	85°F	85°F				



AMERICAN TOXIC DISPOSAL INC

560 SEA HORSE DRIVE WAUKEGAN, IL 60085 TEL 312 336-6067/8

PCB Balances.

I. PCB Balance

The bases for PCB Balance calculation which follow were developed using accepted laboratory procedures and analytical data in section IV-A. Please refer also to paragraph E, Notes.

A. Material in System.

1. Carbon Adsorber Dust

- a. The density was measured as "random loose" packing in a 2 litre graduate.
- b. The depth of the dust was estimated by vacuum removal at approximately 1/2 in. layers of carbon plus dust at a time which indicated successive thickness of 1/2, 1/4, 1/8 in. etc. of which the arithmetic sum is 1 inch. We believe the accuracy to be 1/8 in.. The sample was taken from four vacuum cleaned areas which were screened at 1/16 x 1/16 in. mesh to remove the carbon; it was an aliquot of a thorough mixture.

2. Solids in Dirty Water Storage Tank.

- a. The density was calculated from the dry density obtained above and by "reconstituting" a dust sample to determine water content. (Note that the analyses were on a "wet" basis.)
- b. There was no clearly defined interface of sludge-liquid in the tanks even after some 6 to 8 weeks of settling (Note E-3). However, we obtained high solids concentration material from a pump suction suspended 2-1/2 to 2-3/4 inches from the bottom of the tank and quite a lot at up to 4 inches. We also attempted measurements with a dip-stick. For the final quantity estimate we believe our number to be within - 1/8 and + 1/4; ie. 2-7/8 to 3-1/4 in.
- c. We used 320 ppm as a "within accuracy" average of 319 and 327 from the laboratory data.

3. Carbon in Adsorber (V-6).

Two samples were aggregated from four places in the bed at depths of 2 to 2 1/2 in. and 3 to 3 1/2 in. We therefore selected 4 in. as an effective bed depth (Calgon information, referenced in Exh.VI) and used the average of the analytical results.

4. Dry Fines in System.

The quantity was eye-estimated from several sample pcrts in the system. The average of three

sample analyses was used in the calculation.

5. Fine Solids in System Water.

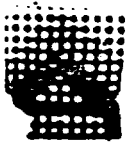
The system contains about 2500lb of water and there is, at our lower than design rates, a tendency for solids to accumulate in some places in the system. We believe the 100 lb to be a reasonable, if not conservative, figure and used the analytical result for the fines in storage which is also conservative.

6. Material in Products

Totals of measured weights have been used and concentrations are weighted averages (Exh.11).

7. Material fed to System.

As '6' above. The quantities shown are calculated dry weights and should have been rounded to - 5 lbs.



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ATD Inc.

PCB Balance

A. Material in system

1. Carbon Adsorber Dust

• For density:

1,230 cc of dust in 2 liter bottle

2,450 grams total weight

720 grams tare of bottle

1,750 grams net = 1.406 grams/cc = 87.7 lb./ft.³

1" of dust in 6 ft. dia. vessel = 2.356 ft.³ = 207 lb.

At 1980 PPM = 0.41 lb. PCB

2. Solids in Dirty Water Storage Tank

87.7 lb./ft.³ dry @ 84% solids = 104.4 lb.ft.³

3" deep in 10 ft. dia. vessel = 2,050 lbs. wet.

At 320 PPM = 0.66 lb. PCB

3. Carbon in Adsorber (v-6)

4" in 6 ft. dia. vessel @ 50 lb./ft.³ = 471 lb.

At 550 PPM = 0.26 lb. PCB

4. Dry Fines in System

60 lbs.

At 513 PPM = 0.03 lbs. PCB

5. Fine Solids in System Water

100 lb.

At 320 PPM = 0.03 lb. PCB

B. Material in Products

1. Autumn '84 Tests

Coarse residue: 25,435.2 lb. @ 1.9 PPM = 0.05 lb. PCB

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2. Spring '85 Tests

Coarse residue: 5,183 lb. @ 0.5 PPM = 0.003 lb. PCB

Cyclone fines: 193 lb. @ 2.2 PPM = 0.004 lb. PCB

3. Hudson River Tests, Spring '85

Coarse residue: 1,968 lb. @ 1.3 PPM = 0.003 lb. PCB

Cyclone fines: 215 lb. @ 1.0 PPM = 0.002 lb. PCB

4. Spike Test, 18 April '85

Coarse residue: 1,490 lb. @ 0.8 PPM = 0.001 lb. PCB

Cyclone fines: 154 lb. @ 7.0 PPM = 0.001 lb. PCB

Total Products = 0.08 lb. PCB

C. Material Fed to System

1. Autumn '84 Tests

26,055.5 lb. @ 43.9 PPM = 1.14 lb. PCB

2. Spring '85 Tests

5,379.1 lb. @ 12.85 PPM = 0.07 lb. PCB

3. Hudson River Tests, Spring '85

2,184.3 lb. @ 8.6 PPM = 0.02 lb. PCB

4. Spike Test, 18 April '85

1,645 lb. @ 206 PPM = 0.34 lb. PCB

Total Material Fed = 1.57 PCB



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D. Overall Balance

1. Material in Systems:

A, 1 through 5, 1.39 lb. PCB

2. Material in Products:

B, 1 through 4, 0.08 lb. PCB

3. Total Accounted For:

1.47 lb. PCB

4. Total Fed:

C, 1 through 4, 1.57 lb. PCB

5. Unaccounted For:

Sampline errors,
plating etc.,

0.10 lb. PCB

E. PCB Balance, Notes:

1. Analyses of the material in the system, article A, have only recently become available.
2. Weighted averages have been used whenever data are available; eg Autumn '84 tests. Where this has not been possible, arithmetic averages have been used; eg A-3, A-4.
3. The material in the dirty water storage tank was thoroughly mixed prior to settling and sampling by means of the circulation lines and jet provided for that purpose. This was done because all of the condensate and fines had been stored including that produced during our shake-down non-tox operation at which time a much greater carry-over of solids was experienced.

Thermal Treatment for The Removal of PCBs and Other Organics from Soil

Robert D. Fox and Edward S. Alperin

IT Corporation, Knoxville, TN

and

Hubert H. Huls

IT Corporation, St. Paul, MN

Thermal separation is an emerging technology for the treatment of contaminated soils and solids. The process removes organic contaminants by indirectly heating the soils and solids to temperatures sufficient to vaporize the hazardous components. The organic vapors in the desorber off-gas are treated either by oxidation in a RCRA-standard secondary combustion chamber or by condensation and conventional treatment of the small amount of the resultant condensate.

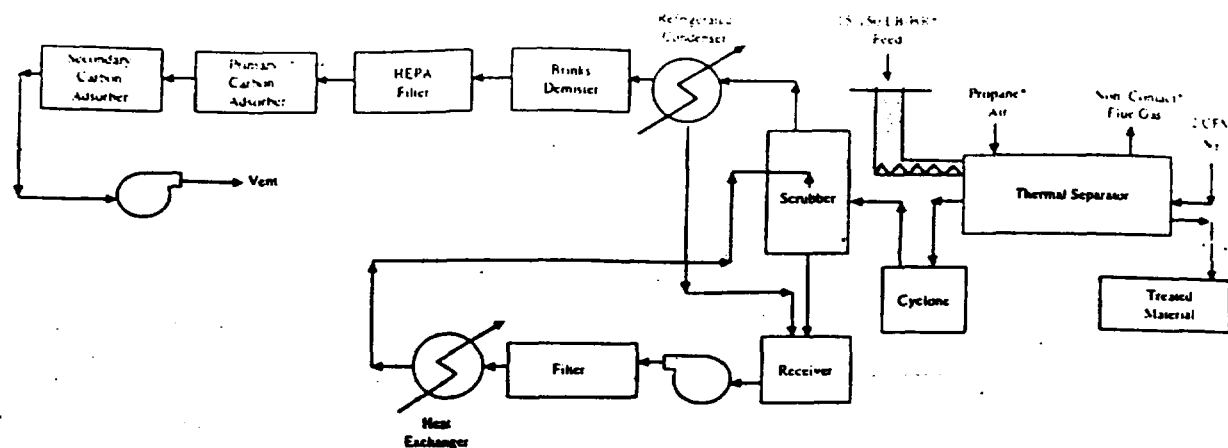
This process had its first successful pilot demonstrations in treating Herbicide Orange contaminated soils at the Naval Construction Battalion Center and at Johnston Island, where dioxin contamination was reduced to less than 1 ppb.

This paper summarizes the results of a series of pilot tests, conducted under a TSCA R&D permit, on 3 soils contaminated with PCBs at concentrations ranging from 250 ppm to 4%. To demonstrate the process on an engineering scale, IT made 13 runs in the pilot thermal separator at rates ranging from 18 to 32 kg/hr. Reported are results on the effect of temperature and residence time on the quality of treated soil. The report also summarizes pilot results on a mixed waste soil and soils contaminated with PAHs.

INTRODUCTION

Thermal separation is an emerging technology for the treatment of contaminated soils and solids. The process removes organic contaminants by indirectly heating the soils and solids to temperatures sufficient to vaporize the hazardous components. Key variables in volatilization performance are soil temperature, time at temperature, and particle size. The organic vapors in the off-gas are treated by either oxidation in a high temperature combustion chamber or by condensation and conventional treatment of the small amount of the resultant condensate.

Indirect heating of soils and solids in a rotating metal chamber as a means of separating contaminants by volatilization offers several process advantages. For example, multiple temperature control zones along the rotating chamber are possible; solids residence time can be readily varied; and the composition and rate of purge gas can be controlled. Indirect heating prevents contact between the contaminants, the direct flame and the combustion products. With indirect heating, the gases exiting the separator consist of containment and soil moisture vapors, entrained particulates, and purge gas. Because the volume of these gases is quite low compared to an incinerator, downstream equipment is small and solids entrainment is min-



* Depends upon level of contaminants and moisture in feed

FIGURE 1. Schematic flow diagram of IT's thermal desorption system.

imized. This also enables condensation to be used as a method to collect the contaminants for either recovery or treatment.

Because it is an alloy metal instead of firebrick, the rotating chamber should require less maintenance. It can be transported easier and the unit can undergo faster heat-up/cool-down cycles.

Another advantage occurs when a lack of contact between the contaminated soil and a direct flame is coupled with the condensation option. In this configuration the system has received a RCRA RD&D permit as a physical/chemical treatment process rather than as an incinerator.

LITERATURE SURVEY

Initial testing of the time, temperature, and particle size relationships for decontamination of soils involved laboratory tests in support of the EPA's Mobile Incineration System [1].

Pilot-scale testing of the indirectly-heated separator was performed at two U.S. Air Force sites contaminated with dioxin from leaking drums of Herbicide Orange [2,3]. Additional pilot-scale tests, which are summarized in this paper, on PCBs are presented in detailed technical reports [4,5]. Treatment of soils contaminated with polynuclear aromatic hydrocarbons (PAHs) by indirectly-heated thermal separation have been reported [6,7,8]. Fundamental studies on the thermal desorption

of organics from soil particles have been reported by researchers at the University of Utah [9]. Bench-scale test results have been reported on thermal separation treatment of contaminated soils from three Superfund sites [10].

Thermal separator systems for treatment of contaminated soils at temperatures of 340°–455°C have been described [11]. This technology will also be demonstrated in the EPA-SITE program [12]. Demonstration of the technology on soil contaminated with volatile organic compounds [13] was funded by the U.S. Army Toxic and Hazardous Materials Agency and the report is available from them.

Two new processes using direct heating of soil to volatilize contaminants at low temperatures have been described [14,15]. One will also be demonstrated in the EPA-SITE program, and the other is scheduled to treat Waukegan Harbor sediment.

EQUIPMENT DESCRIPTION

IT has a thermal separation pilot plant for engineering scale testing and demonstration of the technology on large quantities of contaminated site soils. The pilot plant has a quench and condensation system for handling the desorbed organic contaminants. The pilot plant can treat up to 68 kg/hr of soil at temperatures from 200 to 600°C and residence times of ten minutes to one hour. A block flow diagram of the pilot plant is shown in Figure 1 and a photograph of the thermal separation pilot plant is presented in Figure 2.

The thermal separator pilot plant consists of a continuously rotating 16.5 cm diameter tube (chamber) partially enclosed in a 4.3 meters long gas fired shell. The system is fired with propane at a rate of up to 337 MJ/hr (320,000 BTU/hr) and it transfers $\approx 1/3$ of the heat to the test material.

Soil is fed continuously into the sealed system through a screw feeder and exits through a rotary valve. Purge gas is introduced at the soil discharge end, flows counter current to the soil flow, and exits into the gas quenching and condensing system.

UNIVERSITY OF MINNESOTA TESTS

Under a TSCA R&D permit for the University of Minnesota, pilot scale testing was performed on soil from the Rosemount Research Center (RCC) site. The site was contaminated with PCBs by small businesses, operating between 1966 and 1985,

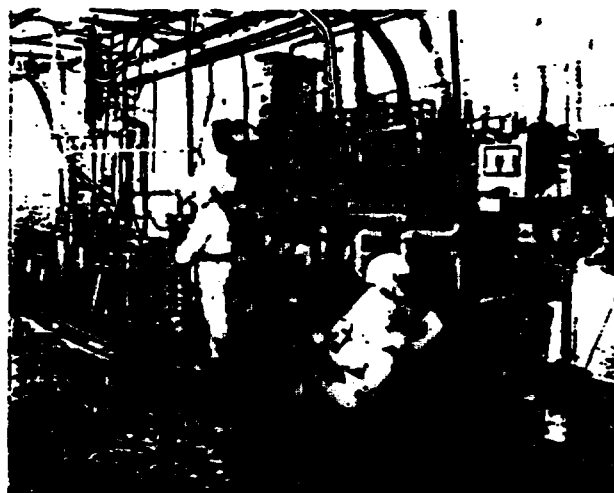


FIGURE 2. Thermal separation pilot plant.

Table 1 University of Minnesota. Pilot Plant Demonstration Test Conditions and PCB Analytical Results

Run	Total Soil Retention Time (min)	Soil Temp (°C)	Soil Feed Rate (lbs/hr) ¹	PCB Concentration (ppm) ¹		
				Soil Type ²	Feed Soil	Treated Soil
01	39	375	40	F	216	<2.0
02	38	452	40	F	220	<2.0
03	39	545	40	F	183	<2.0
04	21	373	74	F	199	<2.0
05	20	449	72	F	247	<2.0
06	21	551	72	F	231	<2.0
07	22	372	70	O	489	<2.0
08	15	380	71	O	546	<2.0
09	22	371	70	O	642 ⁴	<2.0 ⁵
10	15	300	70	O	642 ⁴	<2.0
11	39	379	45	S	44500 ⁵	10.9
11A	23	377	40	S	44500 ⁵	52.3
12	45	450	40	S	44600 ⁶	3.85
12A	22	449	39	S	44600 ⁶	<2.0
13	21	551	70	S	35500	<2.0

¹DCMA Analytical Method²Soil type: O=organic; F=Fill, S=Sand³2.2 lbs = 1 kg⁴Same feed for runs 9 & 10⁵Same feed for runs 11 & 11A⁶Same feed for runs 12 & 12A

that leased portions of the site for electrical equipment salvage. IT tested three different types of site soils:

- a fill soil classified as silty sand and clayey silt contaminated with ≈ 200 ppm of Aroclor 1260;
- an organic soil classified as black to brown stiff clayey and organic silt contaminated with ≈ 500 ppm of Aroclor 1260; and
- a sandy soil consisting of medium dense fine to medium sand contaminated with ≈ 40,000 ppm of Aroclor 1242.

Table 1 provides a summary of the operating conditions and the starting and final concentration of PCBs in the test soils. Each type of soil was successfully treated to a residual PCB concentration of less than 2 ppm as calculated using the Dry

Color Manufacturing Association (DCMA) analytical procedure. This method for the analysis of PCBs in soil was required by the USEPA as a condition of the TSCA R&D permit.

Starting and treated soil samples were also analyzed for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), 2,3,7,8-tetrachlorodibenzo-furan (TCDF), and total tetrafurans using GC/MS. All starting and treated soils were below detectable levels (typically 0.66 ppb) for TCDD. Table 2 shows the results for 2,3,7,8-TCDF and total TCDF. All feed soils had low levels of TCDFs. The fill material and the sandy soil were treated to below detectable levels of both 2,3,7,8-TCDF and total TCDF in experiments at 550°C. The organic soil was not subjected to run conditions above 380°C and, therefore, contained residual levels of the compounds.

Table 2 University of Minnesota, Thermal Separation of PCB Contaminated Soils, Analytical Data Summary Total and 2,3,7,8-TCDF Results

Run	Soil Temp. °C	Feed Soils (ppb)		Treated Soils (ppb)	
		2,3,7,8-TCDF	Total TCDF	2,3,7,8-TCDF	Total TCDF
01	375	0.78 ¹	3.4 ¹	0.44	2.2
02	452	0.78	3.4	ND ²	0.12
03	545	0.78	3.4	ND	ND
04	373	0.78	3.4	0.2	0.71
05	449	0.78	3.4	ND	ND
06	551	0.78	3.4	ND	ND
07	372	NA ³	5.3 ⁴	1.8	7.0
08	380	NA	5.3	1.8	7.6
09	371	NA	5.3	2.5	10.5
10	300	NA	5.3	1.9	6.8
11	379	1.6 ⁵	5.2 ⁵	2.9	16.9
11A	377	1.6	5.2	2.9	16.9
12	450	1.6	5.2	0.2	1.4
12A	449	1.6	5.2	0.2	1.4
13	551	1.6	5.2	ND	ND

¹Composite Feed Sample Runs 1-6²ND = Not Detected³NA = Not Analyzed⁴Composite Feed Sample Runs 7-10⁵Composite Feed Sample Runs 11-13

Table 3 Summary of Typical Pilot Plant Test Results

Soil Source/ Type	Soil Treatment Conditions			Feed Soil			Treated Soil, ppm			
	Temp. °C	Retention Time Minutes	PCBs ppm	2,3,7,8 TCDD ppb	2,3,7,8 TCDF ppb	Total TCDF ppb	2,3,7,8 PCBs ppm	2,3,7,8 TCDD ppb	Total TCDF ppb	TCDF ppb
USAF- Gulfport/sand	560	40	NA	260	NA	NA	NA	ND ¹	NA	NA
	560	19	NA	236	NA	NA	NA	ND	NA	NA
	560	10.5	NA	266	NA	NA	NA	ND	NA	NA
	460	24	NA	233	NA	NA	NA	0.5	NA	NA
USAF- Johnston Island/ crushed coral	550	5.6	NA	48	ND	ND	NA	<0.084	ND	ND
	555	20	NA	56	ND	ND	NA	0.23	ND	ND
DOE Mixed Waste soil/silty sand	550	19	37.5	ND	1.0	ND ²	<2	ND	ND (0.75)	ND ²

¹ Detectability ranged from 0.018 to 0.051 ppb

ND = Not detected

² Detectability ranged from 0.22 to 1.0 ppb

NA = Not applicable

Table 4 Effect of Temperature and Residence Time on PAH Treatment Efficiency

Soil	Temperature (°C)	Time (Minutes)	PAH Removal (%)
A	300	5	96
A	300	9	93
A	400	5	99.5
A	400	9	99.95
B	300	5	96.5
B	300	9	98.9
B	400	5	99.6
B	400	9	99.92
C	300	9	88
C	350	9	96.7
C	400	9	99.1

Interpretation of the PCB and the TCDF data indicates that the PCBs can be removed from actual site soils to below 2 ppm—at temperatures between 300°C and 375°C for low levels of contamination (Runs 1, 4, 7, 9, 15), or 450°C for high levels of contamination (Run 12A). However, removal of the TCDF to below detectable levels required treatment at ~550°C for 20 minutes (Run 13).

OTHER TESTING PROGRAMS

IT has also performed tests for the U.S. Air Force using the thermal separation system on soils contaminated with Herbicide Orange (including dioxin) [2,3]. These tests were conducted in Mississippi and on Johnston Island in the South Pacific. One of the first RCRA RD&D permits issued by the

Table 5 Types of Contaminated Soils and Other Wastes Tested

Soil	Others
PCBs	Oily mill sludge
PAHs	Tetraethyl lead sludge
2,4,-D	Kerosene contaminated clay
2,4,5-T	K106 (Hg-sulfide contaminated sludge)
Dioxins	Styrene tars
Low level radioactivity and organics	API separator sludges
Pentachlorophenol	Creosote Sludge
	Mercury and thorium contaminated sludge

EPA was for The Johnston Island project. The thermal separation process reduced the dioxin content of the treated soils to less than 1 ppb. The organic contaminant vapors were condensed by quenching in an organic solvent and were destroyed by UV photolysis.

The IT thermal separation technology has also been demonstrated in pilot scale tests on two mixed waste soils contaminated with PCBs and low levels of uranium and technetium [5]. Thermal separation treatment separated the PCBs from the radioactive soil, thus, making the latter suitable for disposal as a low level radioactive waste. The PCBs were condensed and collected for off-site disposal; negligible radioactivity was found in the condensate. Table 3 summarizes typical results from these pilot runs.

Pilot scale tests have also demonstrated the ability of the thermal separation technology to treat soils from old manufactured gas plant sites. The contaminants of concern at these sites were polycyclic aromatic hydrocarbons (PAH). Table 4 shows the effect of temperature and residence time on treatment efficiency.

In addition to these pilot plant tests, IT has developed a data base in the application of the IT thermal separation technology for soils contaminated with a wide variety of organic and inorganic contaminants. Table 5 lists the types of contaminants previously tested in laboratory or pilot scale equipment. In addition, three types of laboratory test equipment have been used to understand the key treatment process requirements, such as temperature and residence time, to achieve specific removal efficiencies and clean-up criteria for widely different organic contaminants.

The laboratory testing apparatuses are:

- the tray furnace,
- the tube furnace, and
- the Rotary Thermal Apparatus.

The tray furnace test uses a static but very thin layer of soil to minimize the potential effects of temperature gradients and gas phase diffusion. The test sample is rapidly heated to the test temperature and maintained for a predetermined period. The residue from the test is analyzed for the constituent of interest.

The tube furnace test uses a static 2.5 cm diameter by 15 cm long aliquot of soil confined in an indirectly heated quartz tube. Upon heating, the off-gas from the soil can be collected and analyzed, condensed, or scrubbed to evaluate down-stream processing options.

The rotary thermal apparatus (RTA) shown in the Figure 3 photographs is a 12.5 cm diameter by 36 cm long rotating metal chamber which is indirectly heated with an electric furnace. One to two pound aliquots of soil are batch charged and



FIGURE 3. Rotary thermal apparatus.

heated to the desired temperature and maintained for the test period. Off-gas from the test apparatus is condensed or scrubbed depending on process applications. Residue can be analyzed for constituents of interest and a sufficient amount of treated material is generated for use in TCLP testing.

THERMAL SEPARATION COSTS

The cost considerations in remediating soils or solids contaminated with hazardous materials are:

1. planning and procurement,
2. permitting,
3. site preparation,
4. equipment mobilization,
5. equipment erection/startup,
6. operations,
7. equipment demobilization, and
8. site closure.

The non-operational cost components are highly specific depending on the contaminants involved and the site conditions. The estimated direct operating cost of the thermal separation technology is ~\$80/ton (\$0.088/kg) based on a 10 ton/hr (9,000 kg/hr) system treating soil with 20% moisture. This cost includes \$20/ton (\$0.022/kg) for depreciation and \$60/ton (\$0.066/kg) for labor, utilities, fuel, materials and supplies, and administrative costs.

SUMMARY

Thermal separation offers a cost-effective alternative to incineration for decontaminating soils and solids. The use of a thermal desorption treatment system for a particular contaminated soil problem must be selected based on projected technical performance and cost, along with such factors as regulatory permitting, site characteristics/location, and the presence of other contamination problems at the site (e.g., drummed waste, impounded sludges, etc.).

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RESEARCH

Technical Note 90-117
February 20, 1990

X*TRAX™
TRANSPORTABLE
THERMAL SEPARATOR FOR
SOLIDS CONTAMINATED
WITH ORGANICS

Presented at:
AIR & WASTE MANAGEMENT ASSOCIATION
INTERNATIONAL SYMPOSIUM
on
HAZARDOUS WASTE TREATMENT: TREATMENT
OF CONTAMINATED SOILS

Cincinnati, Ohio
February 5-8, 1990

Presented by:
Chemical Waste Management
Geneva Research Center
2000 S. Batavia Avenue
Geneva, IL 60134

**X*TRAX® TRANSPORTABLE THERMAL SEPARATOR
FOR SOLIDS CONTAMINATED WITH ORGANICS**

Carl Swanstrom and Carl Palmer
Chemical Waste Management, Inc.
2000 S. Batavia Avenue
Geneva, Illinois 60134

The disposal of solid materials contaminated with organics is a growing problem because of the EPA's restrictions on organics in landfills. This paper describes a transportable thermal separator which is an economical alternative to incineration for a broad class of waste materials that have relatively low organic concentrations - typically less than 10%. In the X*TRAX process, the contaminated solids are heated in an indirectly fired rotary dryer to volatilize the organics. The vapors are carried to a gas handling system with an inert gas where they are scrubbed for particulate solids and cooled to condense the organics. The carrier gas is reheated and recycled to the dryer. The condensed organics can be reclaimed, used on or off-site as a supplemental fuel, or destroyed. The X*TRAX system can handle a wide range of organics from high boiling compounds, such as PCBs, to low boiling compounds, such as RCRA regulated solvents. Chemical Waste Management's full scale X*TRAX Model 200 is described, as well as recent results from pilot testing on PCB contaminated wastes using the mobile pilot system.

X*TRAX[®] TRANSPORTABLE
THERMAL SEPARATOR FOR SOLIDS CONTAMINATED WITH ORGANICS

INTRODUCTION

The widespread problem of soils and solids that are contaminated with organic chemicals, coupled with the EPA's increased restrictions on organics in landfills has resulted in the unavoidable fact that millions of cubic yards of soil and solids will have to be treated to reduce or eliminate the organics. Historically, the most likely treatment alternative has been high temperature incineration, which is costly, difficult to permit, and requires lengthy mobilization periods for system installation and trial burns. Chemical Waste Management (CWM) believes that many of these waste streams can be treated using a thermal separation system; in essence, by drying them. Wastes such as contaminated soils, pond or process sludges, filter cakes and others are likely candidates. Laboratory testing by CWM has shown that at low temperatures (500-800°F) many organic compounds including high boiling compounds (PCBs) can be successfully separated from solids such as soil, sand, etc. Thermal separation is now a treatment option with significant advantages in all of the above mentioned areas for a broad class of waste materials that have relatively low organic concentrations - typically less than 10%.

Contaminated solids are heated in an indirectly fired rotary dryer to volatilize the organics. The vapors are carried to a gas handling system with an inert gas where they are scrubbed for particulate solids and cooled to condense the organics. The carrier gas is reheated and recycled to the dryer. The recovered organics can be reclaimed, used on- or off-site as supplemental fuel or destroyed by incineration. This X*TRAX process has been granted U.S. Patent No. 4,864,942.

The X*TRAX system can handle soils and dewatered solids such as pond sludge and filter cakes. Organic contaminants can range from high boiling, semi-volatile compounds such as PCBs, to low boiling, volatile compounds such as RCRA regulated solvents.^{1,2}

This paper will discuss each of the three X*TRAX systems that have been constructed. The laboratory unit is used for performing bench scale treatability studies. The pilot scale system was used to confirm the design parameters and is now used as a demonstration unit. The first commercial unit is in shake down testing and will be moved to a Superfund Site in May, 1990.

X*TRAX PROCESS DESCRIPTION

The X*TRAX system is a separation process to remove volatile or semi-volatile compounds from a solid matrix. Thermal energy is the driving force used to affect the separation.

The system is composed of two main elements, a dryer and a gas treatment system, as shown in Figure 1. The dryer heats the solids and volatilizes the water and organic contaminants. The gas treatment system condenses and collects the volatilized compounds and is the system's air pollution control (APC) portion.

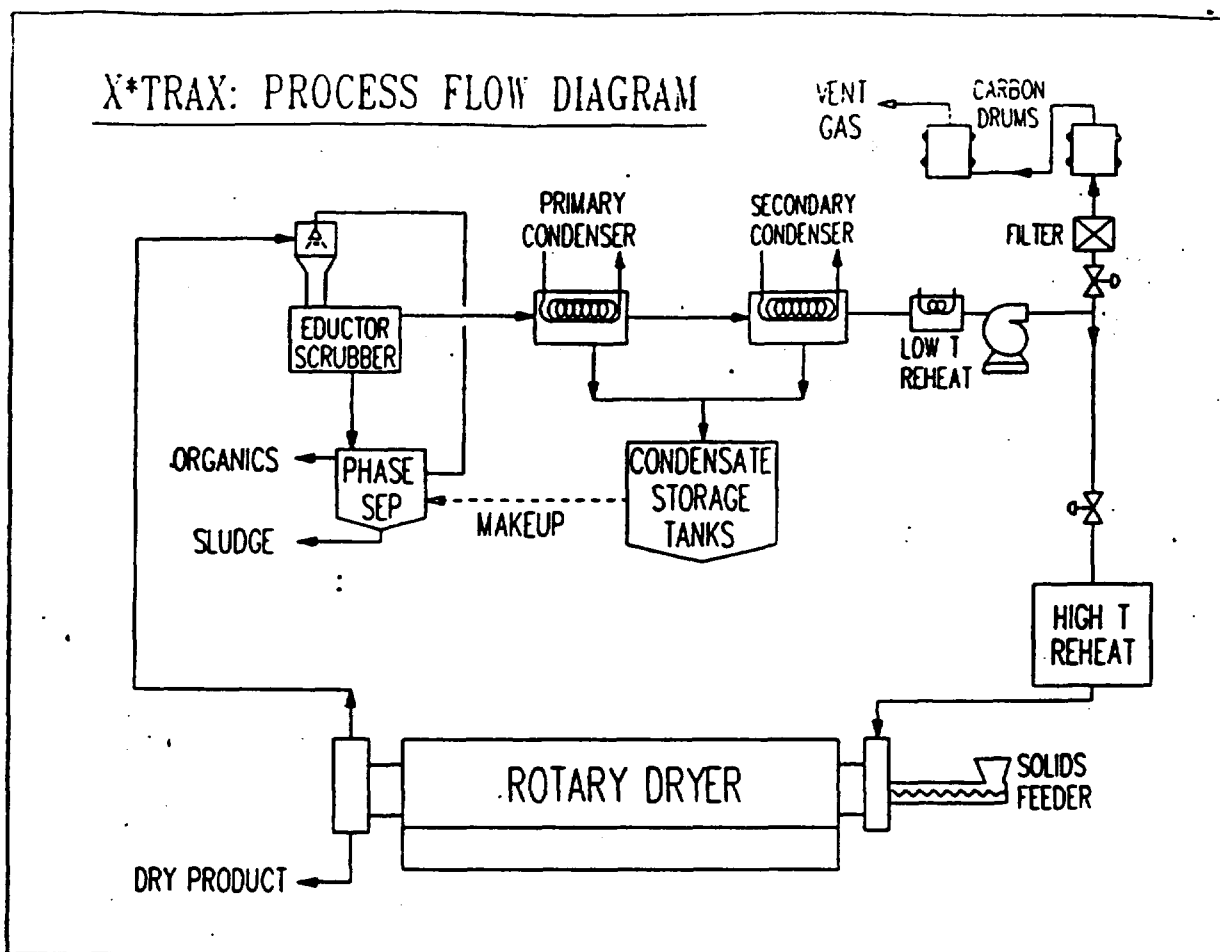


Figure 1

Feed material, which can be either solid or pumpable sludge, is fed into the dryer. The dryer is an externally fired rotary kiln. It is essentially a sealed rotating cylinder with the feed material tumbling inside and the heat source (propane burners) on the outside. Since the dryer is externally fired, the combustion products do not contact the waste material (feed) being processed. The use of an externally fired dryer has two distinct advantages. First, and most important, is that the combustion gases do not pass through the associated air pollution control devices. Propane is a readily available clean burning fuel. Air permits for vent stacks from propane combustors are easily obtained, usually without any required air pollution control devices. This allows the APC devices for the X*TRAX system to be one tenth to one hundredth the size of that for an equivalent capacity incinerator. In addition, the small volume of carrier nitrogen gas discharged makes cleaning it to very high standards quite inexpensive. The second advantage of external firing is that it makes the X*TRAX system a separation process, not an incinerator because no organic combustion occurs. It is usually much easier to permit a separation process than a waste incinerator.

The heated solids are discharged from the dryer as a powdered or granular dry material. For most applications, water will be mixed with the exiting solids to cool them and to prevent dusting. This water will normally be condensate from the gas treatment portion of X*TRAX.

The water and organic materials that are volatilized in the dryer are carried away to the gas treatment system using an inert carrier gas (nitrogen). There, the gases are cooled, particulate material is removed and the water and organics are condensed. The carrier gas is then reheated and recirculated back to the dryer.

The carrier gas first passes through a liquid scrubber where entrained solid particles are removed and the gas stream is cooled to its saturation temperature. The water for this scrubber is continuously recirculated with makeup water being supplied from previously condensed water. The scrubber also removes a portion of the volatilized organics. The recirculated scrubber water continuously passes through a phase separator. The phase separator collects any condensed light organic from the liquid surface and continuously discharges a bottom sludge containing solids, water and organics. The sludge is typically dewatered using a filter press. The filtered liquid is added to the condensed liquid. The dewatered solids are either returned to the feed stream or disposed of.

The scrubbed gas passes to a first heat exchanger where it is typically cooled to 10°F above ambient temperature. This heat exchanger will produce the bulk of the liquid condensate. The carrier gas now goes to a second heat exchanger where it is cooled to 40°F. The liquid condensates from both heat exchangers are mixed and allowed to gravity separate. Floating organics are removed for disposal. Any heavy organics (PCBs or chlorinated solvents) are removed from the bottom for disposal. The remaining condensed water is used to cool and dedust the treated solids exiting the dryer.

The 40°F carrier gas now contains some residual moisture and organics that were present in the feed at levels equal to or less than their equilibrium saturation concentration at 40°F. The carrier gas is then recirculated through a blower. After the blower, 5 to 10% of the carrier gas is vented, and the remainder is heated to 400-700°F before returning it to the dryer.

The process vent gas stream passes through a particulate filter (typically a 2 micron filter) and then through a carbon adsorber, where at least 80% of the remaining organics will be removed. Actual practice has shown removal efficiencies by the carbon ranging from 89 to 98%. This gas is then vented to the atmosphere. A 100 ton per day X*TRAX system would release anywhere from 0.25 to 5 pounds per day of VOCs which is considerably lower than most regulatory constraints.

LABORATORY TESTING PROGRAM

Since January, 1988, CWM has operated a laboratory X*TRAX system at its Riverdale Technical Center in Riverdale, Illinois. This system typically processes 2 to 5 lb/hr. It consists of a 4-inch diameter, 48-inch long electrically heated tube furnace coupled to a small scale gas treatment system that closely simulates that for the pilot and full scale systems. Although it is considered laboratory scale equipment, it occupies a space of about 15 ft by 25 ft.

This unit is used for treatability studies and to screen materials for pilot testing and commercial operations. To date, 23 separate test runs have been performed, with 19 being on actual RCRA and TSCA waste materials. The laboratory system was operated under CWM's TSCA R&D permit for the Riverdale Center, as well as CWM's Illinois authorization for RCRA treatability studies.

In September of 1989 the system was transferred to Chem-Nuclear Systems Inc. (CNSI) in Barnwell, SC. CNSI is using the system to evaluate the applicability of X*TRAX to treating mixed (Radioactive/Hazardous) wastes. A

second laboratory X*TRAX system is being constructed and will be operational in early March at the new CWM R&D facility located in Geneva, IL. A new TSCA R&D permit was granted on January 30, 1990.

Table 1 presents the results on a simulated Superfund soil mixture prepared for EPA. This material was originally referred to by EPA as the Synthetic Analytical Reference Matrix, or SARM. It is now called Synthetic Soil Matrix, or SSM. SSM-1 had high organics concentration and low metals concentration. For both the volatile and semi-volatile organics, better than 90% removal was achieved.

TABLE 1
LABORATORY X*TRAX
SSM-I

Compound	Feed Conc(ppm)	Product Conc(ppm)	% Removal
VOLATILES:			
Acetone	2,600	16.0	99.38
Total Xylene	2,400	9.50	99.60
Ethylbenzene	1,600	5.20	99.68
Styrene	200	< 0.005	> 99.99
Tetrachloroethylene	150	0.094	99.94
Chlorobenzene	110	0.180	99.84
1,2 Dichloroethane	38	0.062	99.84
SEMI-VOLATILES:			
Anthracene	4,650	12.0	99.74
Bis(2-Ethylhexyl)Phthalate	2,380	< 0.33	> 99.99
Pentachlorophenol	497	2.8	99.44

Recently, CWM has performed lab test runs on three soil samples from sites planning on starting remediation in the near future. These are all contaminated soils from large hazardous waste site cleanups. The first was from a Superfund site with primarily PCB contamination, but also with some volatile organic contamination. The soil matrix consisted of silt, clay and gravel. Results are presented in Table 2. Of particular interest with this material was the presence of Arochlor 1260, the highest boiling PCB. The treatment standard for this site was 13 ppm total PCB. Although the treated product had total PCB levels of 17.2 ppm which is above the treatment standard, the 13 ppm treatment standard for this material can most likely be achieved.

TABLE 2
LABORATORY X*TRAX
Silt, Clay, Gravel

Compound	Feed Conc(ppm)	Product Conc(ppm)	% Removal
PCBs	805	17.2	97.9
Total Xylenes	18.8	< 0.125	> 99.3
1,2,4 Trichlorobenzene	24.8	< 0.330	> 98.7
Di-N-Butylphthalate	13.2	< 0.330	> 97.5
Pentachlorobenzene	11.6	< 0.330	> 97.1

The second test run was on a clay soil, also from a Superfund site that was highly contaminated with PCB's with total PCB levels at 3.7% (36,935 ppm). This material had been previously tested in the laboratory system, with the best result being product PCB levels of 534 ppm. By optimizing the operating parameters and gas flow, the PCBs were reduced to below the detection limit of 2 ppm in the product. This outstanding result is very encouraging from a difficult to treat matrix like clay with very high PCB levels in the feed.

The most recent test run was really a series of four tests on soil, pond sludge and mixtures thereof. These materials were all from the same site, which is a large remediation project estimated to have in excess of 500,000 cubic yards of contaminated material. The organic contamination was a complex mixture of chlorinated semi-volatile organics, aromatics and organic solvents. A summary of the test results are presented in Table 3. One of the tests is not reported due to unresolved conflicts in the analytical results.

TABLE 3

Laboratory X*TRAX
Non-PCB Soils, Sludges and Mixtures

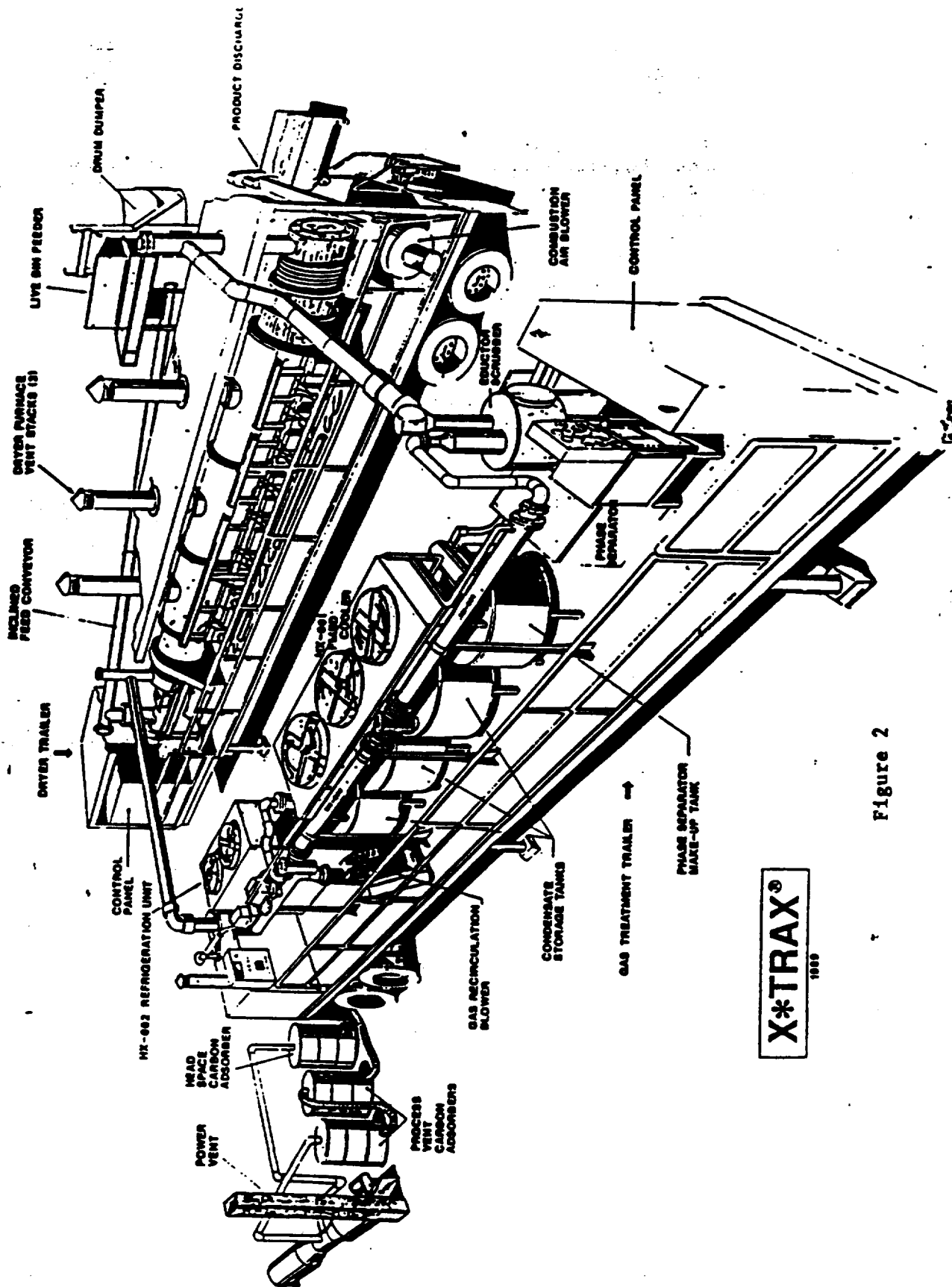
Run No.	Parameter	Concentration	
		Feed	Product
DB0627 Clay Soil	Total Solids (%)	94.1	100
	Ash (%)	92.6	99.8
	3, 3'-Dichlorobenzidine (mg/kg)	1,716	<0.66
	Nitrobenzene (mg/kg)	42.9	<0.33
	Azobenzene (mg/kg)	3,000	4.9
	2-Chloroaniline (mg/kg)	779	ND
	Benzidine (mg/kg)	792	ND
DB0629 Soil/Sludge	Total Solids (%)	73.1	100
	Ash (%)	71.6	99.7
	3,3'-Dichlorobenzidine (mg/kg)	700	<0.66
	Azobenzene (mg/kg)	44.6	ND
	Benzidine (mg/kg)	13.0	ND
DB0710 Sludge	Total Solids (%)	47.0	100
	Ash (%)	44.7	100
	3,3'-Dichlorobenzidine (mg/kg)	503	<0.66
	Azobenzene (mg/kg)	16.8	ND

Treatment standards for this remediation have not yet been developed. If required treatment levels are set on a risk basis, it is very probable that the X*TRAX treated product would be acceptable.

PILOT TESTING PROGRAM

The pilot X*TRAX system is a mobile unit mounted on two semi trailers; one containing the dryer and another containing the gas treatment system. The pilot system has a nominal capacity of 5 tons per day for a feed material containing 30% moisture. Figure 2 is an artists rendering of the pilot X*TRAX system.

The pilot system became operational in January, 1988. It was then tested on simulated contaminated soil feeds until July. During that time over forty tests were performed and in excess of 50 tons of material were processed. These tests proved the operability and reliability of the major pieces of



X*TRAX®

1000

Figure 2

equipment that were chosen for the X*TRAX system. They also established a large body of data on the effectiveness of the separation process for various organic chemicals from a number of different soil matrices. These data are briefly summarized in Table 4. Also, material balance, heat transfer and effluent quality data were also gathered and factored into the design of the full scale X*TRAX Model 200 system.

TABLE 4

PILOT X*TRAX
SURROGATE FEED MATERIALS

Compound	Feed Conc(ppb)	Product Conc(ppb)	% Removal
Methyl Ethyl Ketone	100,900	< 100.0	> 99.90
Tetrachloroethylene	91,000	15.6	99.98
Chlorobenzene	61,810	6.5	99.98
Xylene	56,365	2.8	99.99
1,4 Dichlorobenzene	78,400	1.4	99.99
1,2 Dichlorobenzene	537,000	74.1	99.99
Hexachlorobenzene	79,200	300.0	99.62

The pilot system was then disassembled and transported to the DOE's Oak Ridge Gaseous Diffusion Plant in Tennessee where it was demonstrated on a mixed waste stream containing both RCRA regulated organics and metals and DOE regulated radioactive materials. This test was successfully completed in late October, 1988, and the unit was then decontaminated and refurbished in preparation for its next phase of testing. Radiological material containment was very effective. All tests were run in a minimally controlled area of the facilities parking area, with no radiological related problems.

After refurbishment, the unit was installed in the spring of 1989 at CWM's Kettleman Hills facility in central California for a rigorous series of tests on actual TSCA and RCRA regulated waste materials. Kettleman Hills is a fully permitted RCRA and TSCA treatment, storage and disposal facility. The pilot unit will be operated there at least through 1990 as a research project.

The system is operated under a variety of permits at Kettleman. The most basic of these is an operating permit from Kings County, allowing CWM to have an air emission source. CWM also has a variance from the California Department of Health Services to treat non-RCRA wastes such as California special wastes. The testing on PCB materials was conducted under a three month R&D permit from the EPA's TSCA branch, which expired October 4, 1989. A 90 day extension was granted starting November 1, 1989. CWM has also filed for a RCRA RD&D permit to allow for testing on RCRA regulated materials. This permit request is currently under review and is expected to be approved to allow RCRA testing in May of 1990.

A total of ten PCB containing soils were evaluated under the TSCA R&D permit. The last test was completed on January 26, 1990. Approximately 20 tons of material was processed.

The first test run that was made on a PCB material was conducted on July 27, 1989. The material was a sandy soil with some clay taken from a Superfund site. The site had formerly been used for solvent recycling and was primarily contaminated with PCB's, but also was known to have minor chlorinated solvent contamination. Table 5 is a summary of the performance data from this test run. During the test 4,960 lbs of material were processed in ten hours. The system performed as expected, and a small quantity of organic liquids were

condensed (about 2 quarts) that had PCB concentrations up to 99,100 ppm. The resulting product samples had total PCB concentrations of 8.7-14.7 ppm, which were substantially below the site's treatment standard of 25 ppm. These results demonstrated at a relatively large scale that X*TRAX can separate PCB's from soil and produce a treated product with very low residual PCB concentration.

TABLE 5

PILOT X*TRAX
Sandy Soil with PCBs (0727)

Compound	Feed Conc(ppm)	Product Conc(ppm)	% Removal
PCBs	1,480	8.7	99.4
1,2,4-Trichlorobenzene	2.9	ND	> 99.9
Di-N-Butylphthalate	1.0	0.24	76.0
Bis(2-Ethylhexyl)Phthalate	9.1	0.18	98.0

The second test on a PCB material was on a soil matrix of clay, silt and gravel. This soil was from the same site described previously as being tested in the laboratory unit (see Table 2). As mentioned above, this was a Superfund site with primarily PCB contamination, but also having some solvent contamination. During this second test run 4,484 lb. of material were processed. The results are presented in Table 6. The PCB's were reduced over 99% to 19 ppm.

TABLE 6

Pilot X*TRAX
Clay, Silt & Gravel With PCBs (0810)

Parameter		Concentration Feed	Product	% Removal
Total Solids	(%)	88.5	100	NA
TPH	(mg/kg)	1,400	34	97.6
PCB (1254)	(mg/kg)	2,800	19	99.3
1,2,4-Trichlorobenzene	(mg/kg)	6.8	ND	>98.0
Di-N-Butylphthalate	(mg/kg)	6.9	0.18	97.4
Bis(2-Ethylhexyl) Phthalate	(mg/kg)	4.7	ND	>97.2

It should be pointed out that the solids feed system has presented the most problems during operation of the pilot X*TRAX. Soils with high sand concentrations presented few problems. Soils with high clay content proved very difficult to convey at a constant rate, and sometimes at any rate. Over the last two years four different feed systems have been tried. Each of the first three were modified several times before progressing to the next design. The current feed system has proven itself capable of metering and conveying anything from dry sand to damp clay that had to be picked out of an inverted drum.

X*TRAX Model 200 - Full Scale Production System

System Description

The X*TRAX Model 200 is a full scale production system that was constructed for onsite cleanup of contaminated soil. The system is capable of treating 125 tons per day of contaminated soil with a moisture content of 20%. Like the pilot system, the Model 200 has a rotary dryer and a gas treatment system; however, they are much larger, requiring the use of modular construction techniques. The Model 200 is fully transportable, consisting of three semi trailers, one control room trailer, eight equipment skids and various pieces of removable equipment. Figure 3 is an artist's rendering of the Model 200 system. The area required for the equipment measures about by 120 ft. by 120 ft.

All of the equipment has been designed for over the road transport anywhere in the U.S. or Canada. The dryer is the largest of its kind that can be transported over the road. The components are mobilized to the project site and assembled using a relatively small 15 ton crane. Approximately three to four weeks is required to completely install the equipment. Site preparation involves grading the site level and providing a firm base such as compacted gravel. Concrete footings are not usually required; however concrete housekeeping pads may be required. All skids or trailers that normally contain liquids have integral liquid containment curbs for spill control.

The system requires three phase, 460 volt electric power, propane storage tanks, and a liquid nitrogen storage tank. The electric motors are sized such that the system can be operated from a commercially available diesel generator if electric power is not available at the site.

Operation of the Model 200 involves screening the feed material to remove oversize material such as rocks, wood, etc. The material Handling system limitation is 2.25 inch size materials. Screened material is then placed into the system's feed hopper directly from a front end loader. The feed is then conveyed into the dryer, where the organics are thermally separated from the solids. The hot solids are conveyed from the dryer to the system's product cooler, where previously condensed water is added to cool and dedust the product. Treated product is conveyed from the system and stockpiled, and is then typically returned to the site as backfill after confirmatory analysis shows that the treatment standard has been met.

The gas treatment system employs an eductor scrubber for particulate solids removal, followed by two condensers: the first air cooled and the second refrigerated. This process design is identical to the pilot system. The condensed organic liquids are phase separated in an inclined plate separator and stored in holding tanks for disposal. The scrubber's phase separator has both sludge and scum removal capability. Sludge and scum are accumulated in tanks and then filtered with a skid mounted filter press. Filtrate is recycled to the system, phase separated organics are stored for disposal and filter cake is either reprocessed as feed to the dryer or disposed of.

The X*TRAX Model 200 is monitored from the control trailer, which is a heated and air conditioned portable office trailer. All aspects of system operation can be monitored from the control trailer, and all essential process control parameters can be adjusted. Field operations include feeding the unit, performing liquid transfers between storage tanks and operating the filter press.

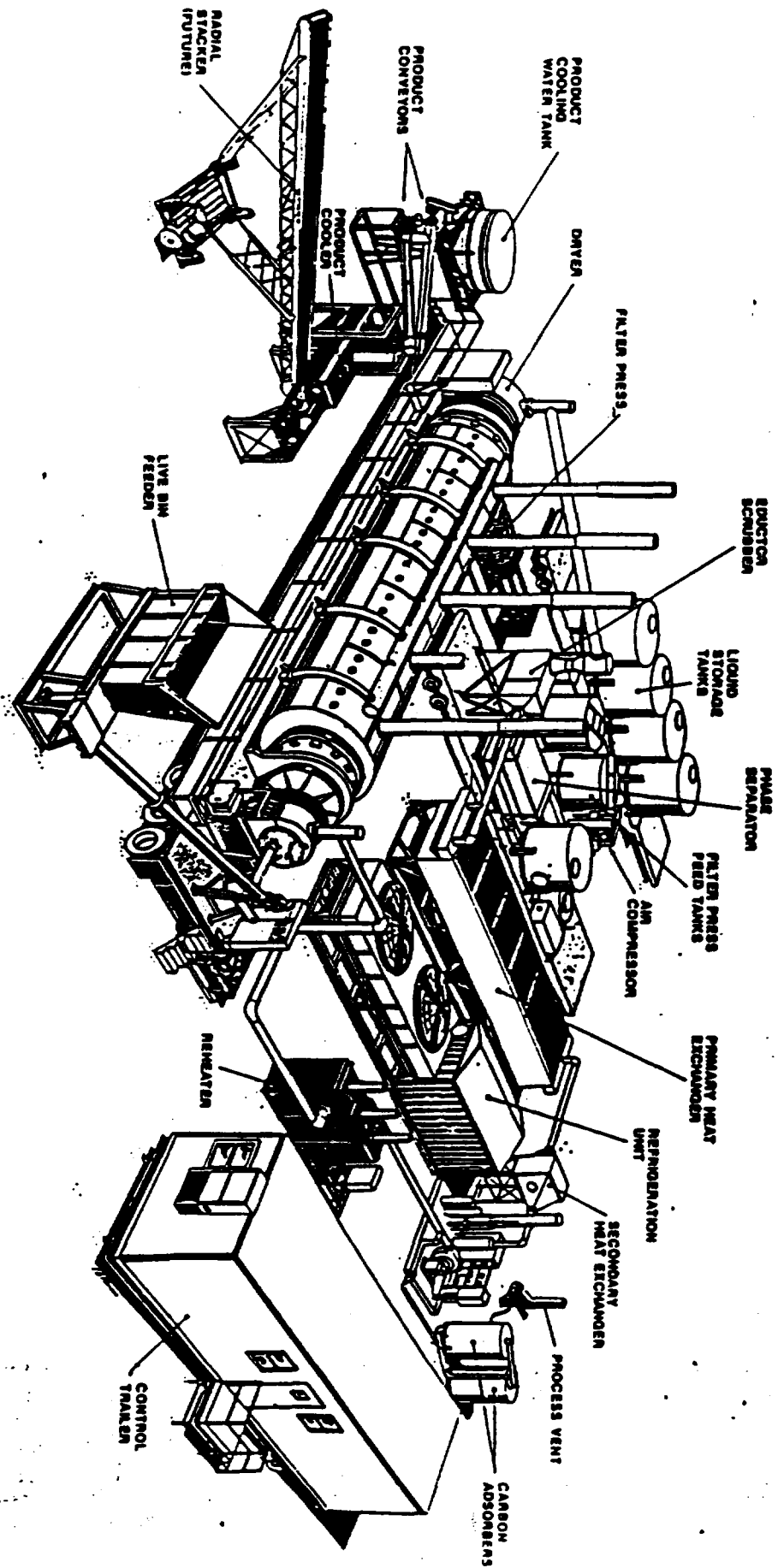


Figure 3

X*TRAX[®]
MODEL 200

Construction and Testing Status

Construction of the X*TRAX Model 200 system has been essentially completed. As of the end of August, the unit is undergoing final checkout prior to a series of performance tests in which the unit will be operated on nonregulated materials to verify function and reliability of all of the pieces of equipment.

The Model 200 system has been operated on non-contaminated feed materials at rates of over 120 tons per day. A new feed system is in the final design stages based on the current feed system being used for the pilot unit. The commercial unit will be transported to North Dartmouth, MA during the second quarter of 1990. The X*TRAX system will be used to remove PCB's from approximately 35,000 tons of soil at the Resolve Site. The condensed oil from X*TRAX will then be dechlorinated.

CONCLUSIONS

The X*TRAX process has been demonstrated to be an effective method for removing organic contaminants from soils. Even very high boiling compounds such as PCB's can be reduced to low levels in the treated soil. The laboratory scale X*TRAX has proven to be ideal for feasibility testing on relatively small samples (50 pounds). The pilot scale system requires at least 2 tons of sample and produces data that can be used to accurately estimate a remediation. The first commercial system will become operational during the second quarter of 1990 on a Superfund site.

Treatment prices are highly dependent on many variables, but will typically range from \$150.00 to \$250.00 per ton of feed processed.

References

1. Swanstrom, C., *X*TRAX® Low Temperature Transportable Treatment Process for Organic Contaminated Solids*, HAZMAT Central, Rosemont, IL, March 14-16, 1989.
2. Daley, P.S., *Cleaning up Sites with On-Site Process Plants*, Environmental Science & Technology, August, 1989.
3. Palmer, C.R., Hollenbeck, P.E., *Sludge Detoxification Demonstration*, Incineration Conference, May 1-5, 1989.

EXHIBIT 3.1-1

LABORATORY X*TRAX - Test Run Summary

RUN #	SAMPLE DESCRIPTION	OPERATING CONDITION			COMPOUND	CONCENTRATION (ppm)		
		Temperature (°F)	Res. Time (min)			Feed	Prod	% Removal
		Shell	Product					
1	Sand contaminated with PCB	800	685	40	Total PCBs	5,942.0	<2.000	>99.970
	Tetrachloroethylene					109.0	<0.005	>99.995
	Trichloroethylene					103.0	<0.005	>99.995
2	Top soil contaminated with PCBs	600	620	92	Total PCBs	330.0	<5.0	>98.50
3	Filtered sludge contaminated with Toluene.	800	700	40	Acetone	40.0	2.000	95.00
	Pea gravel was added to improve the feeding characteristics.				Toluene	6.5	<0.005	>99.92
					Chloroform	1.2	<0.005	>99.58
					Butanone	0.7	0.200	71.43
3A	Filtered sludge contaminated with Toluene.	800	700	92	Toluene	2.4	0.450	81.25
	Fed the as received material.				2-Butanone	2.2	1.000	54.55
					Methylene Chloride	1.4	<0.005	>99.64
4	Sand and floor dry matrix spiked with 1% No. 2 fuel oil and 100 ppm Trichloroethylene.	800	***	40	Trichloroethylene	14.0	<0.05	>99.60
					Total Xylenes	13.0	<0.05	>99.60
					4-Methyl-2-Pentanone	5.0	<0.10	>98.00
5	Synthetic Analytical Reference Matrix (SARM-1). A surrogate superfund soil with high organics and low metals.	800	**	92	Anthracene	4,650.0	182.00	96.09
					Bis(2-ethylhexyl)phthalate	2,380.0	<0.33	>99.99
					Pentachlorophenol	497.0	<1.60	>99.68
					Acetone	2,600.0	16.0	99.38
					Total Xylenes	2,400.0	9.5	99.60
					Ethylbenzene	1,600.0	5.2	99.68
					Styrene	200.0	<0.005	>99.998
					Tetrachloroethylene	150.0	0.094	99.94
					Chlorobenzene	110.0	0.180	99.84
					1,2-Dichloroethane	38.0	0.062	99.84
6	Red clay from South Carolina contaminated with PCBs.	800	650	92	Total PCBs	21,920.0	1,554.0	92.91
					Arochlor 1016	20,100.0	1,390.0	93.08
					Arochlor 1254	1,820.0	164.0	90.99

EXHIBIT 3.1-1 (Continued)

LABORATORY X*TRAX - Test Run Summary

RUN #	SAMPLE DESCRIPTION	OPERATING CONDITION			COMPOUND	CONCENTRATION (ppm)		
		Temperature (°F)	Res. Time			Feed	Prod	% Removal
		Shell	Product	(min)				
7	Wood treaters waste contaminated with pentachlorophenol.	800	650	92	Pentachlorophenol	900.0	17.0	98.11
					Fluoranthene	92.4	4.6	95.02
					Phenathrene	44.0	<3.3	>92.50
					Fluorene	41.0	<3.3	>91.95
					Acenaphthene	40.6	<3.3	>91.87
					Pyrene	40.0	<3.3	>91.75
8	Sand and floor dry matrix spiked with 2% mineral oil and PCBs	800	685	92	Total PCBs	2,569.0	135.0	94.75
					Aroclor 1242	1,379.0	78.0	94.34
					Aroclor 1254	1,190.0	57.0	95.21
9	Wood treaters waste contaminated with pentachlorophenol.	850	620	50	Pentachlorophenol	586.0	7.79	98.67
					Fluoranthene	36.6	<0.33.0	>99.10
					Phenathrene	5.3	<0.33.0	>93.74
					Fluorene	3.7	<0.33.0	>91.06
					Acenaphthene	16.7	<0.33.0	>98.02
					Pyrene	35.6	<0.33.0	>99.07
10	Synthetic Analytical Reference Matrix (SARM - 1). A surrogate superfund soil with high organics and low metals.	850	607	100	Anthracene	2,705	12	99.56
					Bis (2 - ethylhexyl) phthalate	2,630	<0.33	>99.99
					Pentachlorophenol	346	2.8	99.19
					Acetone	25	1.7	93.20
					Total Xylenes	128	<0.05	>99.96
					Ethylbenzene	71	<0.05	>99.93
					Styrene	19	<0.05	>99.74
					Tetrachloroethylene	1	<0.05	>96.43
					Chlorobenzene	3	<0.05	>98.15

EXHIBIT 3.1-1 (Continued)

LABORATORY X*TRAX - Test Run Summary

RUN #	SAMPLE DESCRIPTION	OPERATING CONDITIONS			COMPOUND	CONCENTRATION (ppm)		
		Temperature (°F)	Res. Time			Feed	Prod	% Removal
		Shell	Product	(min)				
11	Red clay from South Carolina contaminated with PCBs	850	630	100	Total PCBs	* 19,404	* 534	97.25
					Aroclor 1016	* 16,441	* 445	97.29
					Aroclor 1254	* 2,963	* 89	97.00
13	Sand contaminated with PCBs	800	666	40	Total PCBs	5,740	5.3	99.91
					Aroclor 1016	3,290	2.5	99.92
					Aroclor 1254	2,450	2.8	99.89
14	Sand contaminated with PCBs	800	515	92	Total PCBs	6,167	<2.0	>99.97
18	Red clayish topsoil from South Carolina contaminated with PCBs	850	***	100	Total PCBs	36,900	<2.0	>99.99

- * In Run #13 the values for the feed concentration were adjusted by a factor of ten because of apparent low level of PCBs in the sample analyzed.

EXHIBIT 3.1-2
EXPERIMENTAL DATA USING CWM PILOT SCALE X*TRAX
Solvent Spiked Feed Results

Run No.	Note	Spike Material	Other Organics	Boiling Pt. (°F)	Feed Conc ug/kg	Product conc. ug/kg % Removal		
						2 hrs	4 hrs	4 hrs
21		Xylene		281 - 292	56,365	7.9	2.8	99.995
			Ethylbenzene	277	13,135	3.3	2.5	99.981
22		Trichloroethylene		189	9,520	1.7	< 1.0	<99.989
			Toluene	231	1,860	4.3	3.6	99.806
			Ethylbenzene	277	4,864	1.0	< 1.0	<99.979
			Xylene	281 - 292	18,110	< 2.0	< 2.0	<99.980
24		Methyl Ethyl ketone		175	100,900	600	< 100	<99.901
25		1,2 Dichlorobenzene		356	75,600	11.4	1.8	99.998
			Toluene	231	1,060	4.6	5.9	99.443
			Ethylbenzene	277	4,340	1.9	1.2	99.972
			Xylene	281 - 292	16,400	6.0	3.5	99.979
26		1,4 Dichlorobenzene		345	78,400	1.8	1.4	99.998
			Toluene	231	6,790	2.4	0.8	99.988
			Ethylbenzene	277	7,550	0.9	0.8	99.989
			Xylene	281 - 292	16,150	3.2	2.9	99.982
28		Chlorobenzene		269	61,810	91.3	6.5	99.990
			Toluene	231	1,470	4.5	< 1.0	<99.932
			Ethylbenzene	277	2,500	4.2	< 1.0	<99.960
			Xylene	281 - 292	7,345	4.5	< 2.0	<99.970
29		Tetrachloroethylene		250	83,900	4.8	< 1.0	<99.999
			Toluene	231	1,720	1.2	< 1.0	<99.942
			Ethylbenzene	277	5,785	< 1.0	< 1.0	<99.983
			Xylene	281 - 292	8,700	< 2.3	< 2.0	<99.977
30		Chlorobenzene		269	37,820	12.9	1.7	99.996
		Tetrachloroethylene		250	44,440	5.1	1.0	99.998
			Toluene	231	981	1.1	< 1.0	<99.898
			Ethylbenzene	277	3,550	< 1.0	< 1.0	<99.972
			Xylene	281 - 292	11,150	< 2.4	< 2.0	<99.982
30 (a)		Chlorobenzene		269	37,820	1.1	< 1.0	<99.997
		Tetrachloroethylene		250	44,440	< 1.0	< 1.0	<99.998
			Toluene	231	981	< 1.0	< 1.0	<99.898
			Ethylbenzene	277	3,550	< 1.0	< 1.0	<99.972
			Xylene	281 - 292	11,150	< 2.0	< 2.0	<99.982

EXHIBIT 3.1-2 (Continued)

EXPERIMENTAL DATA USING CWM PILOT SCALE X*TRAX Solvent Spiked Feed Results

Run No.	Note	Spike Material	Other Organics	Boiling Pt. (°F)	Feed Conc ug/kg	Product conc. ug/kg		% Removal 4 hrs
						2 hrs	4 hrs	
31 (b)		Chlorobenzene Tetrachloroethylene		269	74,000	31.0	46.2	99.938
				250	91,000	11.0	15.6	99.983
			Toluene	231	3,240	14.0	22.2	99.315
			Ethylbenzene	277	11,800	14.1	14.1	99.881
			Xylene	281 - 292	15,940	4.6	9.2	99.942
32 (c)		Hexachlorobenzene		613 - 619	79,200	390	300	99.621
			Toluene	231	2,730	10.0	8.2	99.707
			Ethylbenzene	277	13,600	3.8	6.6	99.951
			Xylene	281 - 292	8,880	< 2.3	< 2.1	<99.976
33 (c)		Chlorobenzene Tetrachloroethylene		269	17,600	41.3	20.7	99.882
				250	18,900	13.9	3.7	99.980
			Toluene	231	4,260	39.5	78.8	98.150
			Ethylbenzene	277	4,770	9.6	12.4	99.740
			Benzene	176	< 500	37.5	67.0	<86.600
			Xylene	281 - 292	3,080	10.3	12.9	99.581
35		Chlorobenzene Trichloroethylene 1,2-Dichlorobenzene		269	1,976	5.5	11.6	99.413
				189	465	7.3	24.6	94.710
				356	19,420	24.9	26.4	99.864
			Toluene	231	< 100	4.1	14.8	<85.200
			Ethylbenzene	277	< 100	< 1.0	3.0	<97.000
			Benzene	176	162	4.1	6.4	96.049
			Xylene	281 - 292	< 200	< 2.3	< 7.3	<96.350
36		Chlorobenzene Trichloroethylene 1,2-Dichlorobenzene		269	34,200	126.0	68.7	99.799
				189	12,900	18.2	32.0	99.752
				356	110,000	198.0	162.0	99.853
			Toluene	231	< 300	69.4	10.0	<96.667
			Ethylbenzene	277	< 300	7.1	8.8	<97.067
			Benzene	176	< 300	22.2	16.0	<94.667
37 (d)		Chlorobenzene 1,2-Dichlorobenzene		269	67,300	121.0	46.9	99.930
				356	537,000	267.0	74.1	99.986
			Toluene	231	< 2,000	24.9	21.2	<98.940
			Ethylbenzene	277	< 2,000	5.7	5.4	<99.730
			Benzene	176	< 2,000	27.2	15.5	<99.225
			Xylene	281 - 292	15,060	18.9	17.9	99.881

Notes: (a) Samples taken at 8 and 12 hours.

(b) Samples taken at 2.3 and 4.3 hours instead of 2 and 4 hours.

(c) Samples taken at 3 and 5 hours instead of 2 and 4 hours.

(d) Samples taken at 2.5 and 5 hours instead of 2 and 4 hours.

TABLE 3 (Continued)

January, 1991

Thermal Desorption

Site Name, State, Region (RCD Date)	Specific Technology	Site Category	Media (Quantity)	Key Contaminants Treated	Status	Lead; Treatment Contractor	Contacts/ Phone
Reich Farms, NJ, 02 (09/30/88)	Enhanced Volatilization	Uncontrolled Waste Disposal	Soil (1,120 cy)	VOCs and Semivolatiles	In Design	PRP Lead	Gary Adamkiewicz 212-264-7592 FIS 264-7592
SMS Instruments (Deer Park), NY, 02 (09/29/89)	In situ Steam Stripping	Military Aircraft Component Overhauled	Soil (1,250 cy)	Solvents (TCE, Xylene, Ethylbenzene, and Chlorobenzene)	In Design	Fund Lead	Abram Foyen 212-264-4706 FIS 264-4706
Waldick Aerospace Devices, NJ, 02 (09/29/87)	In situ Hot Air Stripping	Manufacturing and Electroplating of Plane Parts	Soil (2,500 cy)	TCE, PCE, Cyanide, and Metals	In Design; estimated design completion 12/92	Fund Lead	Larry Granite 212-264-7668 FIS 264-7668
Wanchew, SC, 04 (06/30/88)	Low Temperature Thermal Treatment	Former Dye Production & Solvent Recovery/Recycling Facility	Soil (2,000 cy)	BTEX and SVOCs (Naphthalene)	In Design	PRP Lead	George Reedy 404-347-7791 FIS 247-7791
Outbound Marine/Marathon Harbor, IL, US (01/11/89)	Low Temperature Thermal Extraction (Tocuk Process)	Marine Products Manufacturing	Soil, Sediments (16,000 cy combined)	PCBs	In Design	PRP Lead; Canonic Engineering	Cindy Nolan 312-886-0400 FIS 886-0400

PRELIMINARY

United States
Environmental Protection
Agency

Office of Emergency and
Remedial Response
Washington, DC 20460

Office of
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Cincinnati, OH 45268

Superfund

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Engineering Bulletin

Low-Temperature Thermal Desorption Treatment

Purpose

Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) mandates the Environmental Protection Agency (EPA) to select remedies that "utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable" and to prefer remedial actions in which treatment "permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants and contaminants as a principal element." The Engineering Bulletins are a series of documents that summarize the latest information available on selected treatment and site remediation technologies and related issues. They provide summaries of and references for the latest information to help remedial project managers, on-scene coordinators, contractors, and other site cleanup managers understand the type of data and site characteristics needed to evaluate a technology for potential applicability to their Superfund or other hazardous waste site. Those documents that describe individual treatment technologies focus on remedial investigation scoping needs.¹ Addenda will be issued periodically to update the original bulletins.

Abstract

Low-temperature thermal desorption (LTTD) is an ex situ means to physically separate volatile and some semivolatile contaminants from soil, sediments, sludges, and filter cakes. For wastes containing up to 10% organics or less, LTTD can be used alone for site remediation. It also may find applications in conjunction with other technologies or be appropriate to specific operable units at a site.

Site-specific treatability studies may be necessary to document the applicability and performance of an LTTD system. The EPA Contact indicated at the end of this bulletin can assist in the definition of other contacts and sources of information necessary for such treatability studies.

LTTD is applicable to organic wastes and generally is not used for treating metals and other inorganics. Depending on the specific LTTD vendor selected, the technology heats contaminated media between 200-1000°F, driving off water and volatile contaminants. Offgases may be burned in an after-

burner, condensed to reduce the volume to be disposed, or captured by carbon adsorption beds.

Commercial-scale units exist and are in operation. LTTD has been selected at approximately twelve Superfund sites [14].^{*} Three Superfund Innovative Technology Evaluation demonstrations are planned for the next year.

The final determination of the lowest cost alternative will be more site-specific than process equipment dominated. This bulletin provides information on the technology applicability, limitations, the types of residuals produced, the latest performance data, site requirements, the status of the technology, and sources for further information.

Technology Applicability

LTTD has been proven effective in treating contaminated soils, sludges and various filter cakes. Chemical contaminants for which bench-scale through full-scale treatment data exist include primarily volatile organic compounds (VOCs), semivolatiles, and even higher boiling point compounds such as polychlorinated biphenyls (PCBs) [2][6][9][18]. The technology is not effective in separating inorganics from the contaminated medium. Volatile metals, however, may be removed by higher temperature LTTD systems.

Some metals may be volatilized by the LTTD process as the contaminated medium is heated. The presence of chlorine in the waste can also significantly affect the volatilization of some metals, such as lead. Normally the temperature of the medium achieved by the process does not oxidize the metals present in the contaminated medium [5, p. 85].

The process is applicable for the separation of organics from refinery wastes, coal tar wastes, wood-treating wastes, creosote-contaminated soils, hydrocarbon-contaminated soils, mixed (radioactive and hazardous) wastes, synthetic rubber processing wastes, and paint wastes [1, p. 2][6][15].

Performance data presented in this bulletin should not be considered directly applicable to other Superfund sites. A number of variables such as the specific mix and distribution of contaminants affect system performance. A thorough characterization of the site and a well-designed and conducted treatability study is highly recommended.

^{*} [reference number, page number]

Table 1
RCRA Codes for Wastes Treated
by Low-Temperature Thermal Desorption

Wood Treating Wastes	K001
Dissolved Air Flotation (DAF) Float	K048
Slop Oil Emulsion Solids	K049
Heat Exchanger Bundles Cleaning Sludge	K050
American Petroleum Institute (API) Separator Sludge	K051
Tank Bottoms (lead)	K052

Table 2
Effectiveness of Low-Temperature Thermal
Desorption on General Contaminant Groups
for Soil, Sludge, Sediments, and Filter Cakes

Contaminant Groups		Effectiveness			
		Soil	Sludge	Sediments	Filter Cakes
Organic	Halogenated volatiles	■	▼	▼	■
	Halogenated semivolatiles	■	▼	▼	■
	Nonhalogenated volatiles	■	▼	▼	■
	Nonhalogenated semivolatiles	■	▼	▼	■
	PCBs	■	▼	▼	▼
	Pesticides (halogenated)	■	▼	▼	▼
	Dioxins/Furans	■	▼	▼	▼
	Organic cyanides	▼	▼	▼	▼
	Organic corrosives	□	□	□	□
Inorganic	Volatile metals	■	▼	▼	▼
	Nonvolatile metals	□	□	□	□
	Asbestos	□	□	□	□
	Radioactive materials	□	□	□	□
	Inorganic corrosives	□	□	□	□
	Inorganic cyanides	□	□	□	□
Reactive	Oxidizers	□	□	□	□
	Reducers	□	□	□	□
■ Demonstrated Effectiveness: Successful treatability test at some scale completed					
▼ Potential Effectiveness: Expert opinion that technology will work					
□ No Expected Effectiveness: Expert opinion that technology will not work					

Table 1 lists the codes for the specific Resource Conservation and Recovery Act (RCRA) wastes that have been treated by this technology [1, p.2][6][15]. The indicated codes were derived from vendor data where the objective was to determine LTDD effectiveness for these specific industrial wastes. The effectiveness of low-temperature thermal desorption on general contaminant groups for various matrices is shown in Table 2. Examples of constituents within contaminant groups are provided in "Technology Screening Guide For Treatment of CERCLA Soils and Sludges" [5, p. 1-14]. This table is based on the current available information or professional judgment where no information was available. The proven effectiveness

of the technology for a particular site or waste does not ensure that it will be effective at all sites. For that, the treatment efficiencies achieved will be acceptable at other sites. For the ratings used for this table, demonstrated effectiveness means that, at some scale, treatability was tested to show the technology was effective for that particular contaminant and medium. The ratings of potential effectiveness, or no expected effectiveness are both based upon expert judgment. Where potential effectiveness is indicated, the technology is believed capable of successfully treating the contaminant group in a particular medium. When the technology is not applicable or will probably not work for a particular combination of contaminant group and medium, a no-expected-effectiveness rating is given. Another source of general observations and average removal efficiencies for different treatability groups is contained in the Superfund Land Disposal Restrictions (LDR) Guide #6A, "Obtaining a Soil and Debris Treatability Variance for Remedial Actions," (OSWER Directive 9347.3-06FS, July 1989) [22] and Superfund LDR Guide #6B, "Obtaining a Soil and Debris Treatability Variance for Removal Actions," (OSWER Directive 9347.3-07FS, December 1989) [20].

Limitations

The primary technical factor affecting LTDD performance is the maximum bed temperature achieved. Since the basis of the process is physical removal from the medium by volatilization, bed temperature directly determines which organics will be removed.

The contaminated medium must contain at least 20 percent solids to facilitate placement of the waste material into the desorption equipment [2, p. 9]. Some systems specify a minimum of 30 percent solids [7, p. 6].

As the medium is heated and passes through the kiln or desorber, energy is lost in heating moisture contained in the contaminated soil. A very high moisture content can result in low contaminant volatilization or a need to recycle the soil through the desorber. High moisture content, therefore, causes increased treatment costs.

Material handling of soils that are tightly aggregated or largely clay, or that contain rock fragments or particles greater than 1-1.5 inches can result in poor processing performance due to caking. Also, if a high fraction of fine silt or clay exists in the matrix, fugitive dusts will be generated [5, p. 83] and a greater dust loading will be placed on the downstream air pollution control equipment [7, p. 6].

The treated medium will typically contain less than 1 percent moisture. Dust can easily form in the transfer of the treated medium from the desorption unit, but can be mitigated by water sprays. Normally, clean water from air pollution control devices can be used for this purpose.

Although volatile organics are the primary target of the LTDD technology, the total organic loading is limited by some systems to up to 10 percent or less [4, p. II-30]. As in most systems that use a reactor or other equipment to process wastes, a medium exhibiting a very high pH (greater than 11) or very low pH (less than 5) may corrode the system components [5, p. 85].

There is evidence with some system configurations that polymers may foul and/or plug heat transfer surfaces [2, p. 9]. Laboratory/field tests of LTTD systems have documented the deposition of insoluble brown tars (presumably phenolic tars) on internal system components [8, p. 76].

High concentrations of inorganic constituents and/or metals will likely not be effectively treated by LTTD. The maximum bed temperature and the presence of chlorine can result in volatilization of some inorganic constituents in the waste, however.

Technology Description

LTTD is any of a number of processes that use either indirect or direct heat exchange to vaporize organic contaminants from soil or sludge. Air, combustion gas, or inert gas is used as the transfer medium for the vaporized components. LTTD systems are physical separation processes and are not designed to provide high levels of organic destruction, although the higher temperatures of some systems will result in localized oxidation and/or pyrolysis. LTTD is not incineration, since the destruction of organic contaminants is not the desired result. The bed temperatures achieved and residence times designed into LTTD systems will volatilize selected contaminants, but typically not oxidize or destroy them. System performance is typically measured by comparison of untreated soil/sludge contaminant levels with those of the processed soil/sludge. Soil/sludge is typically heated to 200 - 1000° F, based on the LTTD system selected.

Figure 1 is a general schematic of the low-temperature thermal desorption process.

Waste material handling (1) requires excavation of the contaminated soil or sludge or delivery of filter cake to the system. Typically, large objects greater than 1.5 inches are screened from the medium and rejected. The medium is then delivered by gravity to the desorber inlet or conveyed by augers to a feed hopper [1, p. 1].

Significant system variation exists in the desorption step (2). The dryer can be an indirectly fired rotary asphalt kiln, a

single (or set of) internally heated screw auger(s), or a series of externally heated distillation chambers. The latter process uses annular augers to move the medium from one volatilization zone to the next. Additionally, testing and demonstration data exist for a fluidized bed desorption system [7].

The waste is intimately contacted with a heat transfer surface, and highly volatile components (including water) are driven off. An inert gas, such as nitrogen, may be injected in a countercurrent sweep stream to prevent contaminant combustion and to vaporize and remove the contaminants [1, p. 1][6]. Other systems simply direct the hot gas stream from the desorption unit [2, p. 5][9].

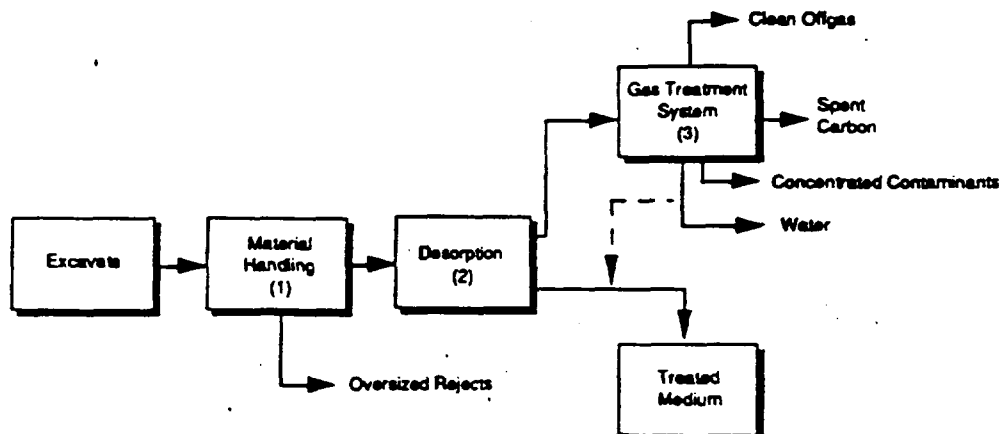
The actual bed temperature and residence time are the primary factors affecting performance in LTTD. These parameters are controlled in the desorption unit by using a series of increasing temperature zones [1, p. 1], multiple passes of the medium through the desorber where the operating temperature is sequentially increased, separate compartments where the heat transfer fluid temperature is higher, or sequential processing into higher temperature zones [10][11]. Heat transfer fluids used to date include hot combustion gases, hot oil, steam, and molten salts.

Offgas from desorption is typically processed (3) to remove particulates. Volatiles in the offgas may be burned in an afterburner, collected on activated carbon, or recovered in condensation equipment. The selection of the gas treatment system will depend on the concentrations of the contaminants, cleanup standards, and the economics of the offgas treatment system(s) employed.

Process Residuals

Operation of LTTD systems typically creates up to six process residual streams: treated medium, oversized medium rejects, condensed contaminants and water, particulate control system dust, clean offgas, and spent carbon (if used). Treated medium, debris and oversized rejects may be suitable for return onsite.

Figure 1
Schematic Diagram of Low Temperature Thermal Desorption



Condensed water may be used as a dust suppressant for the treated medium. Scrubber purge water can be purified and returned to the site wastewater treatment facility (if available), disposed to the sewer [2, p. 8] [1, p. 2] [6, p. 2], or used for rehumidification and cooling of the hot, dusty media. Concentrated, condensed organic contaminants are containerized for further treatment or recovery.

Dust collected from particulate control devices may be combined with the treated medium or, depending on analyses for carryover contamination, recycled through the desorption unit.

Clean offgas is released to the atmosphere. If used, spent carbon may be recycled by the original supplier or other such processor.

Site Requirements

LTTD systems are transported typically on specifically adapted flatbed semitrailers. Since most systems consist of three components (desorber, particulate control, and gas treatment), space requirements on site are typically less than 50 feet by 150 feet, exclusive of materials handling and decontamination areas.

Standard 440V, three-phase electrical service is needed. Water must be available at the site. The quantity of water needed is vendor and site specific.

Treatment of contaminated soils or other waste materials require that a site safety plan be developed to provide for personnel protection and special handling measures. Storage should be provided to hold the process product streams until they have been tested to determine their acceptability for disposal or release. Depending upon the site, a method to store waste that has been prepared for treatment may be necessary. Storage capacity will depend on waste volume.

Onsite analytical equipment capable of determining site-specific organic compounds for performance assessment make the operation more efficient and provide better information for process control.

Table 3
PCB Contaminated Soils
Pilot X*TRAX™

Matrix	Feed (ppm)	Product (ppm)	Removal (%)
Clay	5,000	24	99.5
Silty Clay	2,800	19	99.5
Clay	1,600	4.8	99.7
Sandy	1,480	8.7	99.1
Clay	630	17	97.3

Source: Chemical Waste Mgmt., Inc.; 5 TPD unit

Performance Data

Several LTTD vendors report performance data for their respective systems ranging from laboratory treatability studies to full-scale operation at designated Superfund sites [12][15][17]. These data are included as a general guideline to the performance of LTTD equipment, and may not be directly transferrable to a specific Superfund site. Good site characterization and treatability studies are essential in further refining and screening the LTTD technology.

Chem Waste Management's (CWM's) X*TRAX™ System has been tested at laboratory and pilot scale. Pilot tests were performed at CWM's Kettleman Hills facility in California. Twenty tons of PCB- and organic-contaminated soils were processed through the 5 TPD pilot system. Tables 3 and 4 present the results of PCB separation from soil and total hydrocarbon emissions from the system, respectively [6].

Weston has applied its low-temperature thermal treatment (LT²) system to various contaminated soils at bench-scale through full-scale projects [19]. Table 5 presents a synopsis of system and performance data for a full-scale treatment of soil contaminated with No. 2 fuel oil and gasoline at a site in Illinois.

Canonie Environmental has extensive performance data for its Low Temperature Thermal Aeration (LTTA™) system at full-scale operation (15-20 cu. yds. per hour). The LTTA™ has been applied at the McKin (Maine), Ottati and Goss (New Hampshire) and Cannon Engineering Corp. (Massachusetts) Superfund sites and the South Kearney (New Jersey) site. Table 6 presents a summary of Canonie LTTA™ data [9].

T.D.I. Services, Inc. has demonstrated its HT-5 Thermal Distillation Process at pilot- and full-scale for a variety of RCRA-listed and other wastes that were prepared to simulate American Petroleum Institute (API) refinery sludge [1]. The company has conducted pilot- and full-scale testing with the API sludge to demonstrate the system's ability to meet Land Ban Disposal requirements for K048 through K052 wastes. Independent evaluation by Law Environmental confirms that

Table 4
Pilot X*TRAX™
TSCA Testing - Vent Emissions

Total Hydrocarbons (ppm-V)				
Before Carbon	After Carbon	Removal (%)	VOC (lbs/day)	PCB* (mg/m ³)
1,320	57	95.6	0.02	<0.00056
1,031	72	93.0	0.03	<0.00055
530	35	93.0	0.01	<0.00051
2,950	170	94.2	0.07	<0.00058
2,100	180	91.4	0.08	<0.00052

Source: Chemical Waste Mgmt., Inc.; 5 TPD unit

*Note: OSHA permits 0.50 mg/m³ PCB (1254) for 8-hr exposure.

the requirements were met, except for TCLP levels of nickel, which were blamed on a need to "wear-in" the HT-5 system [3, p. ii].

Remediation Technologies, Inc. (ReTec) has performed numerous tests on RCRA-listed petroleum refinery wastes. Table 7 presents results from treatment of refinery vacuum

filter cake. Tests with creosote-contaminated clay and coal tar-contaminated soils showed significant removal efficiencies (Tables 8 and 9). All data were obtained through use of ReTec's 100 lb/h pilot scale unit processing actual industrial process wastes.

Table 5
Full-Scale Performance Results
for the LP System

Contaminant	Soil Range (ppb)	Treated Range (ppb)	Range of Removal Efficiency
Benzene	1000	5.2	99.5
Toluene	24000	5.2	99.9
Xylene	110000	<1.0	>99.9
Ethyl benzene	20000	4.8	99.9
Napthalene	4900	<330	>99.3
Carcinogenic			
Priority PNAs	<6000	<330-590	<90.2-94.5
Non-carcinogenic			
Priority PNAs	890-6000	<330-450	>62.9-94.5

Source: Weston Services, Inc.; 10 TPH unit

Table 6
Summary Results of the LTA™
Full-Scale Cleanup Tests

Site	Processed	Contaminant	Soil (ppm)	Treated (ppm)
S. Kearney	16000 tons	VOCs PAHs	177.0 (avg.) 35.31 (avg.)	0.87 (avg.) 10.1 (avg.)
McKin	>9500 cu yds 2000 cu yds	VOCs PAHs	ND-3310	ND-0.04 <10
Ottati & Coss	4500 cu yds	VOCs	1500 (avg.)	<0.2 (avg.)

Source: Canonie Environmental; 40-50TPH unit

Table 7
ReTec Treatment Results Refinery
Vacuum Filter Cake (A)

Compound	Original Sample (ppm)	Treated Sample (ppm)	Removal Efficiency (%)
Napthalene	<0.1	<0.1	—
Acenaphthylene	<0.1	<0.1	—
Acenaphthene	<0.1	<0.1	—
Fluorene	10.49	<0.1	>98.9
Phenanthrene	46.50	<0.1	>99.3
Anthracene	9.80	<0.1	>96.6
Fluoranthrene	73.94	<0.1	>99.8
Pyrene	158.37	<0.1	>99.9
Benzo(b)anthracene	56.33	1.43	97.5
Chrysene	64.71	<0.1	>99.9
Benzo(b)fluoranthene	105.06	2.17	97.9
Benzo(k)fluoranthene	225.37	3.64	98.4
Benzo(a)pyrene	477.44	10.25	97.8
Benzo(ghi)perylene	163.53	5.09	96.6
Indeno(123-cd)pyrene	122.27	4.16	96.6
Treatment Temperature: 450°F			

Source: ReTec, Inc.; 100 lb/h unit

Table 8
ReTec Treatment Results Creosote -
Contaminated Clay

Compound	Original Sample (ppm)	Treated Sample (ppm)	Removal Efficiency (%)
Napthalene	1321	<0.1	>99.9
Acenaphthylene	<0.1	<0.1	—
Acenaphthene	293	<0.1	>99.96
Fluorene	297	<0.1	>99.96
Phenanthrene	409	1.6	99.6
Anthracene	113	<0.1	>99.7
Fluoranthrene	553	1.5	99.7
Pyrene	495	2.0	99.6
Benzo(b)anthracene	59	<0.1	>99.99
Chrysene	46	<0.1	>99.8
Benzo(b)fluoranthene	14	2.5	82.3
Benzo(k)fluoranthene	14	<0.1	>99.8
Benzo(a)pyrene	15	<0.1	>99.9
Dibenzo(ab)anthracene	<0.1	<0.1	—
Benzo(ghi)perylene	7	<0.1	>99.4
Indeno(123-cd)pyrene	3	<0.1	>99.3
Treatment Temperature: 500°F			

Source: ReTec, Inc.; 100 lb/h unit

Table 9
ReTec Treatment Results Coal Tar -
Contaminated Soils

Compound	Original Sample (ppm)	Treated Sample (ppm)	Removal Efficiency (%)
Benzene	1.7	<0.1	>94
Toluene	2.3	<0.1	>95
Ethylbenzene	1.6	<0.1	>93
Xylenes	6.3	<0.3	>95
Naphthalene	367	<1.7	>99
Fluorene	144	<0.2	>99
Phenanthrene	223	18	91.9
Anthracene	112	7.0	93.8
Fluoranthrene	214	15	93.0
Pyrene	110	11	90.0
Benzo(b)anthracene	56	<1.4	>97
Chrysene	58	3.7	93.6
Benzo(b)fluoranthene	45	<1.4	>97
Benzo(k)fluoranthene	35	<2.1	>94
Benzo(a)pyrene	47	<0.9	>98
Benzo(ghi)perylene	24	<1.1	>95
Indeno(123-cd)pyrene	27	<6.2	>77
Treatment Temperature: 450°F			

Source: ReTec, Inc.; 100 lb/h unit

Recycling Sciences International, Inc. (formerly American Toxic Disposal, Inc.) has tested its Desorption and Vaporization Extraction System (DAVES), formerly called the Vaporization Extraction System (VES), at Waukegan Harbor, Illinois. The pilot-scale test demonstrated PCB removal from material containing up to 250 parts per million (ppm) to levels less than 2 ppm [7].

RCRA LDRs that require treatment of wastes to best demonstrated available technology (BDAT) levels prior to land disposal may sometimes be determined to be applicable or relevant and appropriate requirements for CERCLA response actions. LTDD can produce a treated waste that meets treatment levels set by BDAT but may not reach these treatment levels in all cases. The ability to meet required treatment levels is dependent upon the specific waste constituents and the waste matrix. In cases where LTDD does not meet these levels, it still may, in certain situations, be selected for use at the site if a treatability variance establishing alternative treatment levels is obtained. Treatability variances are justified for handling complex soil and debris matrices. The following guides describe when and how to seek a treatability variance for soil and debris: Superfund LDR Guide #6A, "Obtaining a Soil and Debris Treatability Variance for Remedial Actions" (OSWER Directive 9347.3-06FS, July 1989) [22], and Superfund LDR Guide #6B, "Obtaining a Soil and Debris Treatability Variance for Removal Actions" (OSWER Directive 9347.3-07FS, December 1989) [20]. Another approach could be to use

other treatment techniques in series with LTDD to obtain desired treatment levels.

Technology Status

Significant theoretical research is ongoing [16][21], as well as direct demonstration of LTDD through both treatability testing and full-scale cleanups.

A successful pilot-scale demonstration of Japanese soils "roasting" was conducted in 1980 for the recovery of mercury from highly contaminated (up to 15.6 percent) soils at a plant site in Tokyo. The high concentration of mercury made recovery and refinement to commercial grade (less than 99.99 percent purity) economically feasible [13].

In this country, LTDD technologies are the selected remedy for one or more operable units at the following sites: McKin (Maine), Ottati & Goss (New Hampshire), Cannon Engineering Corp. (Massachusetts), Fulton Terminals (New York), Greenwood Chemical Co. (Virginia), Resolve (Massachusetts), Wide Beach (New York), and Tinker Air Force Base (Oklahoma).

Most of the hardware components of LTDD are available off the shelf and represent no significant problem of availability. The engineering and configuration of the systems are similarly refined, such that once a system is designed full-scale, little or no prototyping or redesign is required.

On-line availability of the full-scale systems described in this bulletin is not documented. However, since the ex situ system can be operated in batch mode, it is expected that component failure can be identified and spare components fitted quickly for minimal downtime.

Several vendors have documented processing costs per ton of feed processed. The overall range varies from \$80 to \$350 per ton processed [18][6, p. 12][9][2, p. 9]. Caution is recommended in using costs out of context because the base year of the estimates vary. Costs also are highly variable due to the quantity of waste to be processed, term of the remediation contract, moisture content, organic constituency of the contaminated medium, and cleanup standard to be achieved. Similarly, cost estimates should include such items as preparation of Work Plans, permitting, excavation, processing itself, QA/QC verification of treatment performance and reporting of data.

EPA Contact

Technology-specific questions regarding LTDD may be directed to:

Michael Gruenfeld
U.S. Environmental Protection Agency
Risk Reduction Engineering Laboratory
Releases Control Branch
2890 Woodbridge Ave.
Bldg. 10 (MS-104)
Edison, NJ 08837
FTS 340-6625 or (908) 321-6625

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(FAX -0087)

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BENCH AND PILOT-SCALE DATA

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BRIAN BELL
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(219) 926-8651

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LOW TEMPERATURE THERMAL TREATMENT (LT3)
FULL SCALE SYSTEM - 7.5 TPH
FIELD REMEDIATIONS / DATA

MEMORANDUM

DATE: November 23, 1988

SUBJECT: Draft Demonstration Test Plan: Pilot Test of Thermal Stripping of JP4 and Other VOCs from Soils at Tinker Air Force Base, Oklahoma City, Oklahoma (September 1988)

FROM: Linda Galer

TO: John Kingscott

I have reviewed the subject document, which is a draft of the plan to demonstrate Roy F. Weston's patented Low-Temperature Thermal Treatment (LT³) process at Tinker Air Force Base under the auspices of the U.S. Army Toxic and HM Agency (USATHAMA). The planned project is to process about 800 cy of soil contaminated with jet propulsion fuel (JP-4) and hydrocarbon solvents (primarily trichloroethylene). The project was originally scheduled for October 1988 through January 1989, including about three weeks for set up and five to eight weeks for the field tests. Weston is planning to provide process equipment, conduct the test, conduct stack emissions testing, and provide on- and off-site analytical services. Weston apparently has conducted full-scale operations using this technology between 9/1/88 and 10/31/88 to treat diesel fuel and gasoline contaminated soil at a site in Springfield, IL

In order to familiarize you and me with the technology and proposed project, I have summarized these below. The plan appears well thought out, and overall, I believe will be an excellent SITE project. Lastly, I give a few concerns I have about the project.

Site Background

____ A sludge dump operated on the Tinker Air Force Base from 1961-1968 was used to dispose of waste oils and liquids from industrial operations and sludge from petroleum lubricants. Investigation of the sludge dump in March 1988 indicated a hydrocarbon layer floating on the groundwater which closely resembled jet fuel (JP-4), and contained other hydrocarbon solvents. High concentrations of solvents, primarily TCE, also found in water and soil samples. A final investigation in May 1988 delineated boundary of sludge dump area through soil borings. It was found that soil was contaminated with petroleum hydrocarbons and solvent to a 12-ft depth. Estimated about 900 cy of sludge-contaminated soil present.

Technology Description

Weston's Low-Temperature Thermal Treatment (LT³) process is designed to treat soils contaminated with volatile organics and petroleum hydrocarbons without heating the soil matrix to combustion temperatures. The thermal processor is an indirect heat exchanger used to dry and heat contaminated soil to about 400°F, which evaporates or strips the VOCs from the soil. The organic vapors are processed in an afterburner or fume incinerator. The equipment is mounted on three tractor trailer beds and can be set up in two days.

The plan is to excavate 800 cy of soil from the Landfill 3 sludge area and stockpile it next to the unit on a 6-mil plastic liner, and covered with plastic. Soil will be transported to the system by a backhoe or front-end loader and fed into the unit at 30-min intervals. Soil is screened to less than 2 inches, passes through a power shredding device, then placed on the 2-foot wide and 40-ft long feed conveyor mounted at a 60 degree angle. The conveyor is designed to convey 15,000 lb/hr of wet soil. Oversized material is removed and stockpiled for replacement in excavation area. The conveyor discharges to a 5-ftx5-ft surge hopper which holds 8,000 lb of soil, enough for 30 minutes of operation. The screws of the thermal processor extend into the bottom of the surge hopper, withdrawing feed material to create a "live bottom hopper" effect. (During 4 runs, solvent [hexane or water] will be applied by spray nozzles as the feed soil is placed into the surge hopper.)

The thermal processor consists of two jacketed troughs (20ft long) one above the other, each of which houses four intermeshed screw conveyors (18in. in diameter). Soil is carried across the upper tier of the processor by the screws, discharged at the end to the second tier via gravity, and moved in the opposite direction across the second tier, exiting at the same end it entered. Hot oil is circulated through the hollow shafts and flights of the screw conveyors and the hollow trough jackets. Residence time and soil temperature are varied by changing rotational speed of the screws and hot oil temperature.

Soil is discharged from the thermal processor into a horizontal screw conveyor, then to a second screw conveyor, or conditioner, equipped with water spray nozzles to cool the discharge material and minimize fugitive dust emissions. Conditioned soil passes onto an belt conveyor and discharged into a collection dump truck or hopper.

Hot oil can be heated to a maximum of 650°F by a gas-fired burner. The combustion gases released from the hot oil system, which are at 700°F and low oxygen content, is used as a hot and relatively inert carrier in the thermal processor to sweep or remove volatiles from the processor.

Sweep air and volatiles from the thermal processor are drawn into a fabric filter for particulate removal. Dust from the filters drops to the bottom, collected in bins and manually removed. The hot gases (300°F) exit the filter into a condenser which removes condensable water vapor and organics. Condensed liquid is collected in a trap and pumped to the water treatment system. Off-gases go to the afterburner, as gas-fired fume incinerator operating at 1,800°F. The afterburner chamber is 10ft long, 8ft wide, and 8ft high. The hot exhaust from the afterburn is mixed with ambient air to cool it, and directed to the acid gas scrubber, where any acid gases are neutralized with sodium hydroxide. Scrubber blowdown liquor used to prevent salt buildup is collected for on-site treatment.

Liquid from the condenser is collected and pumped to gravity oil-water separator. The light organic phase is removed by a skimmer, and the water phase is directed to a series of two carbon adsorption columns. The scrubber liquor is also treated by the carbon. The treated water is stored and sprayed on the treated soil for dust control. The organic phase is stored in a 55-gallon drum for off-site disposal.

Test Objectives

The objectives of the test are to demonstrate the following:

- o effectiveness of technology in removing JP-4 and TCE from soils
- o impact on performance caused by varying operational parameters (e.g., hot oil temp. and soil residence time)
- o impact on performance caused by adding solvents to the soils (e.g., hexane, water)
- o optimum range of operational parameters
- o compliance with Federal, State, or local air emissions requirements

Operational Plan

Fifteen test runs are planned, as follows:

- o stack tests during 3 test runs
- o 9 test runs to evaluate optimum operating conditions [3x3 matrix of 3 soil residence times (30, 45, and 60 min) and 3 hot oil temperatures (400, 500, and 600°F)]
- o 4 test runs to determine the effect of adding solvent to feed soil to enhance stripping or volatilization simultaneously with varying soil residence time and hot oil temperature

Criteria

The stated criteria for a successful demonstration are:

- o processed soil achieving Goal Cleanup Level (ppb) for contaminants (listed in a table)
- o optimum operating conditions that effectively decontaminate the soil at a practical soil residence time and attainable hot oil temperature

Comments

As I stated earlier, the project appears to be a good candidate for a SITE demonstration. I have a few comments and concerns about this project, which are given below.

- o Another sampling point prior to screening/shredding step desirable to determine loss of volatiles during feed preparation.
- o We would want to determine how well fugitive emissions will be controlled prior to soil entering the thermal processor.
- o We should evaluate the adequacy of solvent blending, since this could affect performance.
- o The power shredder described in the text is not shown on Figure 2.1 or 5.1. Fig. 2.1 shows a "vibrating screen" and 5.1 a "classifier."
- o Can the Air Force redispense of the treated soil into excavated area? I would think they would have to wait until the RI/FS was completed, the ROD signed, and the cleanup levels established.
- o Lastly, we would want to design the test, not to meet the goals stated in the draft plan, but to determine how performance varied with residence time and oil temperature, in particular, just how well the unit could treat.

Attachment 7



DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, OMAHA DISTRICT
215 NORTH 17TH STREET
OMAHA, NEBRASKA 68102-4978



July 2, 1991

REPLY TO
ATTENTION OF

Environmental Branch

Mr. Robert Swale
U.S. Environmental Protection Agency
Region V
230 South Dearborn Street
Chicago, Illinois 60604

Dear Mr. Swale:

Enclosed are the comments on the Draft Feasibility Study of the American Chemical Services National Priorities List (NPL) Site at Griffith, Indiana, that you requested.

The Hydrologist suggested that the document be forwarded to the U.S. Army Corps of Engineers, Omaha District, Operations Division, Regulatory Section, for the additional 404/permit review comments. These comments will be forwarded to you at a later date.

If you have any questions, please contact Ms. Jean Palensky, telephone: (402) 221-7765.

Sincerely,

Randal K. Petersen, P.E.
Chief, Environmental Branch
Engineering Division

Enclosure

CORPS OF ENGINEERS
ENGINEERING REVIEW COMMENTS

Page 1 of 1
Date: 14 Jun 91

Omaha District

To: Jean Palensky, CEMRO-ED-EA

Design Phase: Draft Feasibility

Designed by: Warzyn, Inc.

Project: American Chemical Services Project Location: Griffith, IN

Comments by: M.D. Wichman

Branch/Section: CEMRO-ED-DK

Drawing # or Paragraph #	Item #	Comments
Wetlands	1	<p>Additional Federal Regulations affecting discharge to natural wetlands include:</p> <p>Executive Order 11990, Protection of Wetlands, stating actions taken by Federal Agencies must minimize the degradation of wetlands.</p> <p>Executive Order 11988, Floodplain Management, Preserve the natural as well as the beneficial values associated with floodplains.</p> <p>Clean Water Act, sets discharge limits of 30 mg/L BOD, 30 mg/L TSS, pH of 6.0 to 9.0. These levels represent the minimum secondary treatment level required, the actual NPDES permit may be more strict.</p> <p>National Environmental Policy Act of 1969, 40 CFR 6, calls for a detailed Environmental Impact Statement (EIS).</p> <p>Fish and Wildlife Coordination Act, 16 USC 661-666 as amended by Public Law 89-72 (7/9/65) requires consultation with Federal Agencies, the U.S. Fish and Wildlife Services and the National Marine Fisheries Services, on proposed actions affecting fish and wildlife resources.</p> <p>Endangered Species Act of 1973, 16 USC 1531 et seq as amended by Public Law 98-237 (6/25/84) may also be applicable if endangered or threatened species are present.</p>

10 April 1991

TO: JEAN PALENSKY; CEMRO-ED-EA
REGARDING: WETLANDS ISSUE FOR ACS NPL SITE, GRIFFITH, INDIANA
FROM: ANGELA WATMORE; CEMRO-ED-EF

According to the Feasibility Study for American Chemical Services NPL Site, here on out referred to as ACS, several RCRA listed hazardous wastes exist. Consequently, all of the other non-listed wastes at the site must be treated and handled as hazardous waste due to the derived-from and mixture rules of RCRA Subtitle C. See 40 CFR 261 and 262. Once a listed waste is always a listed waste, it does not matter how well the waste is treated. A de-listing process must be pursued to allow the treated waste to be considered non-hazardous in most cases, otherwise the land disposal restrictions would apply and the waste would not be allowed to be surface discharged. See Petitions to Delist Hazardous Wastes: A Guidance Manual, PB85-194488, 1985, 40 CFR 148, and RCRA 3004(m). However, this on-site surface discharge will be governed by the Federal Water Pollution Control Act (FWPCA), and the fact that the wastewater from the dewatering process will be treated to a level adequate to meet National Pollutant Discharge Elimination System (NPDES) requirements alleviates the water characterization from RCRA. Therefore the de-listing process is not required to exempt the water from RCRA hazardous regulations after treatment of the water, since the water is being regulated under NPDES. See 40 CFR 261.4.

The FWPCA Sections 301 and 402 prohibit the discharge of pollutants unless authorized by a permit from EPA or an authorized state. A FWPCA 404 Permit from the U.S. Army Corps of Engineers and a NPDES Permit (See 40 CFR Parts 122-125) are usually required prior to surface discharging any possible pollutants. However, CERCLA Section 121(e) provides permit waivers for any remedial action done on-site. This is only an administrative/procedural exemption, the substantive requirements of the permit must still be met. For example, this would include any location restrictions that prevent discharge of treated water to wetlands and Federal, State, or local cleanup levels. The Indiana Water Pollution Control Law Section 13-1-6-6 requirement for state certification would have to be substantively met also.

EPA's Policy Statement on wetlands (See 38 FR 10834, March 20, 1973) states that EPA intends to preserve the wetland ecosystems by protecting them from destruction by waste discharge. The addition of harmful waste should be kept below a level that will alter the natural, physical, chemical, or biological integrity of the wetland area and that will insure no significant increase in nuisance organisms through biostimulation. Id. at 10834. In accordance with the National Environmental Policy Act of 1969 (NEPA), EPA will not grant funds for waste treatment that would involve a destruction of wetlands, unless there is no other existing alternative. EPA seeks to have the most environmentally protective alternative selected. After prudent consideration of the ARARs for this wetlands issue and review of the ACS FS, as long as the water is treated to adequate levels that are agreed by EPA and the State or local agencies, the water could then be discharged to the wetlands which are located on-site. Possibly cleaning the water up to Ambient Water Quality Levels would help assure no damage

to the wetlands, however this is not required. The wastewater treatment technologies proposed in considering alternatives for a CERCLA site are required to meet BCT/BAT requirements, pursuant to FWPCA Section 301(b). CERCLA Section 121(d)(2)(B)(i) requires that the water quality criteria to be met be determined based on the designated or potential use of the water, the media affected, the purposes of the criteria, and current information. The upshot of this argument is that the discharger would be acting as a POTW of sorts, and acting under the substantive requirements of the NPDES Permit requirements. 40 CFR 261.4 exempts remedial actions that are being regulated by NPDES Permit facilities.

In summary, according to United States of America v. Hobbs, 32 ERC 2091 (DC Eva. 1990), EPA has independent authority to determine whether certain property is subject to the FWPCA, even though the U.S. Army Corps of Engineers initially determines whether said property is wetlands. If EPA determines that the remedial action selected is meeting the substantive intent of the FWPCA NPDES Permit process, then the surface discharge will not be governed by RCRA, and the de-listing process would not be required. Additionally, the waste water would fall under Indiana's NPDES Program, which has been approved by EPA. See 56 FR 21158, May 7, 1991. Under the authority of the FWPCA, Indiana may develop rules to allow implementation of the FWPCA. See Indiana Water Pollution Law Section 13-1-3-4 and 13-1-3-8. Therefore, the remedial action must meet the substantive requirements of the Indiana NPDES. If all of this substantive requirements are met to assure public, environment, and specifically wetland protection from any hazardous waste contamination, then the water may be discharged to the on-site wetlands. It is important to work with the Regional 404/Wetlands Office during this process.

CORPS OF ENGINEERS
ENGINEERING REVIEW COMMENTS

Page 1 of 1
Date: 06/13/91

Omaha District		To: CEMRO-ED-EA	
Design Phase: FEASIBILITY STUDY		Designed by: WARZYN, INC.	
Project: ACS NPL SITE		Project Location: GRIFFITH, IN.	
Comments by: BILL DOAN		Branch/Section: CEMRO-ED-HE	
Drawing # or Paragraph #	Item #	Comment	Action

P. 3-17 1

DISCHARGE OF TREATED WATER TO WETLANDS-- A hydrologic water budget analysis of the existing wetlands and wetlands w/treated water should be performed. This would allow a comparison of pre and post project conditions to determine if discharging treated water into the wetlands would negatively affect the hydrologic regime of the wetlands. Negative effects may be; changes in natural seasonal fluctuations in water surface depths, increases in overall water depths, etc.

CEMRO-ED-HF

19 June 1991

MEMORANDUM FOR CEMRO-ED-EA

SUBJECT: REQUEST FOR SERVICES

Project Name - American Chemical Services

Project Location - Griffith, Indiana

1. Reference your Memorandum dated 5 June 1991, subject as above.
2. It is not clear who will do the sampling associated with National Pollutant Discharge Elimination System (NPDES) discharge permits. This could be an expensive item especially if conducted over a period of many years. In addition, no mention is made of what will be sampled.
3. The subject document contains no discussion of wetland impacts. Impacts could occur associated with substituting treated surface water with groundwater as well as changing seasonal flow regimes.
4. The subject document states that treated water could be used to flush residual levels of contaminants from sediments in the wetlands and along ditches. In addition, the document states that biological activity in wetlands could be enhanced to further reduce potential residual levels of contaminants. Flushing or disturbing such contaminants could result in exposing wildlife and humans to impacts.
5. No 404 permits should be required since only water is being discharged to the wetlands. The NPDES permits discussed in the subject report are issued on a site specific basis by the appropriate state agency. Water quality personnel will provide assistance pertinent to NPDES permitting if required. It is suggested that a copy of Draft Feasibility Study be forwarded to Operations Division for additional permit review comments.

18 June 1991

MEMORANDUM FOR CEMRO-ED-EA (PALENSKY)

SUBJECT: American Chemical Services, Griffith, Indiana; Comments on Feasibility Study

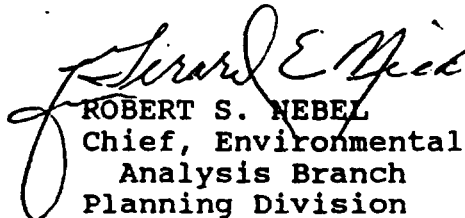
1. The Corps of Engineers has no jurisdiction in this case with regard to discharge of treated water to wetlands. The discharge of treated water to wetlands after pumping and treating will probably require the approval of the State office responsible for water quality.

2. Wetlands are protected under:

- a. Executive Order 11990, Protection of Wetlands
- b. Section 404 of the Clean Water Act
- c. Various State requirements

3. We are returning copy of Draft Feasibility Study and Draft Remedial Investigation Report - ACS NPL Site - Griffith, Indiana.

Encl


ROBERT S. NEBEL
Chief, Environmental
Analysis Branch
Planning Division

Figures